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SCREW-THREADS.

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[*Read at the Stated Meeting, Wednesday, November 16, 1887.*]

JOSEPH M. WILSON, President, in the Chair.

The subject of screw-threads has been discussed by engineers and machinists for so long a time, and so continuously, that it might seem as though it would be worn 'thread'-bare, but until a form of thread is adopted that can be more readily produced of a standard size, and more easily maintained than the threads now in common use, the theme will continue to be a good subject for discussion.

During the year of 1857, Sir Joseph Whitworth, of England, prepared a table for screw-threads having a particular form, and offered it to the engineers of Great Britain, with a recommendation that it be adopted as an interchangeable system throughout the Kingdom. It was received with favor, and has been generally adopted in Great Britain, with good results.

In the year 1864, Mr. Wm. Sellers, then the President of the FRANKLIN INSTITUTE, read a paper before the INSTITUTE on the importance of having an interchangeable system in this country. He described the Whitworth system, and explained some of its advantages and defects, and proposed a system of his own, using about the same number of threads per inch as Whitworth's, but substituting a flat top and bottom for the rounded ones, and changing the angle of the sides from 55° to 60°.

A committee was appointed to examine the system, and make a report thereon.

This committee reported in favor of the system, and the INSTITUTE requested the manufacturers of the country to adopt it.

Much good has resulted from this recommendation, and yet an immense amount of trouble has been brought about by it.

The necessity at that time for an interchangeable system was so great, that any practicable plan proposed by a well-known authority would have been hailed with delight.

The number of threads per inch proposed in the Sellers table was probably a fair average of those in use, but the slight change in shape from the common V-thread, then in use, was so difficult to obtain in practice, that the system has been very slow in coming into general use. It is now nearly twenty-four years since it was introduced, and still, at this time at least, twenty or twenty-five per cent. of the manufacturers of the country do not use it, preferring, for one reason or another, to use systems of their own.

The most extensive manufacturers of bolts and nuts in this locality—the well known firm of Hoopes & Townsend—did not adopt the Sellers system till 1881, although they had, for years before, supplied such of their customers as required it, with bolts and nuts having this thread.

Referring to the Transactions of the INSTITUTE for April of 1887, it appears that the engineers of the United States Army and Navy adopted the system in 1869, the Master Mechanics' Association in 1870, the Master Car Builders' Association in 1872, and although all the railroads in the country are represented in these two associations, some of the most extensive railroad corporations did not adopt the system till years later. The Chicago, Burlington and Quincy, the Chicago, Rock Island and Pacific, and the New York Central and Hudson River Railroad adopted it in 1883

Since the exchanging of cars from one road to another has become so universal, the necessity for an interchangeable system of bolts and nuts has grown more apparent; and all the roads are falling into line in adopting the Sellers system, not because the system is considered perfect or altogether satisfactory, but from necessity.

The members of the two associations, the Master Car Builders and Master Mechanics, having charge of the rolling stock of all the railroads in the United States, know better how to appreciate the benefit to be derived from having an interchangeable system of bolts and nuts, than any other class of mechanics, as they are called upon every day in the year to furnish bolts or nuts to replace those lost or broken, on the rolling stock of what are termed foreign cars, while in use on the roads of which they have charge. It is quite probable that these men use more bolts and nuts, than all the rest of the mechanics in the country combined.

It has been found that nearly all the railroads of this country use the Sellers system, so far as the number of threads is concerned, yet many of them do not use the other dimensions. Some of them use taps considerably over-size, and some do not use the flat top and bottom.

The principal difficulty in obtaining taps and dies of the Sellers form and size, is owing to the thread being made in section, a trapezoid, whose base is made equal to the pitch of the threads, less a distance equal to the flat top, and whose altitude or height is necessarily the fractional part of an inch, that is almost always a decimal fraction in the thousandths, or else an indeterminable measure.

As it is impracticable to measure in the ordinary machine shop closer than the one-thousandth part of an inch, the figures after the third decimal are left off, usually adding one to the third figure, if the fourth is five or over. A difference of five ten-thousandths of an inch will make a tight or loose fit.

Sir Joseph Whitworth stated in one of his addresses before the Society of Civil Engineers, in 1857, that one ten-thousandths of an inch in difference in the diameters of a plug and ring, made a loose fit; and illustrated the fact by exhibiting a pair of gauges.

I have before me a steel bolt with a nut fitted to it, of which both diameters, in the nut, are one-thousandth of an inch larger than the corresponding diameters of the bolt. On showing it to a member of the INSTITUTE, who was a member of the committee in

1864, he remarked that I should have required better workmanship. At the time this bolt was made, I had determined to keep the size of the bolt the same as that given in the table, and to make the diameters in the nut larger than on the bolt, otherwise the nut could not be put on the bolt. I was at a loss to know what difference to recommend, and I failed to get any light on the subject till I found out by experiment. I was aware that a car axle turned from four- to six-thousandths of an inch larger than the hole in a car wheel, would require from twenty to thirty tons pressure to force it into the wheel, while two or three thousands still larger for the axle would burst the wheel.

I had nuts chased four-thousandths, two-thousandths, and one one-thousandth of an inch larger than the bolt. The first two were much too large, and the latter is loose enough to justify the above criticism. It is my impression, however, that one-thousandth would not be too large in practice using iron for bolts and nuts; for a little oil on the bolt, and any roughness that might remain on the thread would cause it to turn tight enough.

Going back again to the Sellers thread, the width of the flat surface at the top and bottom of the thread is necessarily so small that it can not be measured, and can only be obtained by the fit-and-try process. This flat surface must be exactly right, otherwise if the tool used for chasing the thread was too wide, the fit would be too loose; if too narrow, the fit would be too tight.

I have prepared a chart, illustrating the different kinds of threads, showing their exact shapes and comparative proportions.

This chart is made to represent the thread on a bolt one inch in diameter, with eight threads to the inch. The part that is section-lined represents the thread in the nut.

You will observe the Whitworth thread with its 55° angle and its top and bottom rounded.

The altitude of the triangle thus formed, with its apex having an angle of 55°, is considerably greater than that formed with an angle of 60°, but when the altitude is divided by six, and two-sixths are removed, the remaining four-sixths are very nearly equal to the remaining six-eighths of the triangle of the Sellers form after the two-eighths have been removed.

I have drawn some dotted lines over one of the threads of the Sellers form, to represent the Whitworth thread.

You will see that there is so little difference, that the nuts of one form will probably fit the bolts of the other, and it is quite likely that, in practice, taps and dies made in a common shop, to be either a Whitworth or a Sellers form, would be as near one as the other. Since writing the above, I have been informed by a member of the committee of 1864, that locomotives built in this city for use on the roads of Canada, have bolts with the Sellers form of thread, and when they need repairs, nuts of the Whitworth standard are used on the bolts, and are found to be equally serviceable.

A prominent maker of bolts and nuts has informed me that they make a great many bolts for foreign orders that require the Whitworth standard thread; that they make them to the Whitworth gauge as near as it is possible to work, but they do not have to make special nuts, as they find the nuts from their common stock, with Sellers thread, to answer just as well.

It is claimed that the 60° angle of the Sellers thread is more easily found than an angle of 55°. This is, of course, true, but if a tool ground perfectly to an angle of 60° is not properly placed in the tool post of the lathe, it will not cut a thread with an angle of 60°. As bolts that are not perfectly cut are in very common use, and do not cause much trouble, the question is not an important one. The width of the flat or rounded surface is so infinitesimally small that the difference between them is of little importance, and the difficulty claimed by some in making is more imaginary than real.

The *greatest difficulty* in obtaining a standard size and form of thread applies to the V-form, the Sellers, or the Whitworth form alike. It is the difficulty in calipering the diameters at the top and bottom of the threads in the nuts and on the bolts. If the bearing surface of the threads does not correspond exactly in the nut and on the bolt, they soon adjust themselves when a strain is applied, but if the nut is too loose there is no remedy.

Most manufacturers make the hole in the nut too large for the bolts for which they are intended. This is done for the purpose of making the taps last as long as possible. The result is that the thread of the bolt only bears on its outer edge. On examining any commercial list of nuts, it will be found that the hole in the nut is so large that the thread is only half the depth of the thread on the bolt.

One of the difficulties in the way of getting taps of a uniform size, is owing to the fact that all steel does not expand alike in hardening and tempering; consequently, a difference in size will be found in a lot of taps that have been made with the greatest care.

One of the largest manufacturers of bolts and nuts in the city informs me that they order upward of 100 taps at a time of one size, and when they are received they carefully gauge them and make two or more sizes, and use them of the different sizes for special purposes.

The many difficulties experienced make it impossible for any ordinary machine shop to verify the standard, except by comparing with standard gauges that only one shop in the United States (so far as I am aware) attempts to make.

There are quite a number of manufacturers that make taps for sale; some make very good ones, and some make intolerably bad ones. No shop not especially prepared can afford to make its own taps. The taps of the best manufacturers vary in size and unless the purchaser can afford to have a set of expensive gauges he cannot tell which are right, the large ones or the small ones.

The Sellers or the Whitworth system answers very well where the bolts are chased in a lathe in a comparatively small way, and where bolts and nuts are used of a size much larger than necessary for the purpose, and where economy in the use of material is not considered, but when bolts have to be cut on a bolt-cutter by the thousand, it is behind the age. These criticisms apply with equal force to the Whitworth thread.

A good system of threads for use in bridge work, car building and common machinery construction, that would be interchangeable and give at the same time from twenty to thirty per cent. more strength to the bolts—than those in common use—is practicable and desirable. To have a thread suitable for all kinds of work is not practicable.

The pipe manufacturers have a system of their own—a very good one. Neither the Sellers nor the Whitworth system is applicable to pipe work. For long lines of pipe, the manufacturers use a taper thread by which tight work may be more easily obtained, and the greatest strength at the couplings secured.

This kind of thread was used in the couplings for splicing the wires in the cables of the Brooklyn bridge, whereby ninety-five per cent. of the strength of the wire was obtained.

While engaged in car building some years since, I gave the subject considerable attention, and in the year 1879, I made some tests, of which I will give an account.

It occurred to me that the bolts in common use were weakened more than was necessary in cutting the Sellers thread on them, and the nuts were more than twice as strong as the bolt, for it was known that a nut, the thickness of one-half of the diameter of the bolt, would break the bolt without stripping when a strain was applied great enough to destroy one or the other; so I considered the question whether it was not possible to equalize the strength of the bolt and nut by making a thread with less depth.

When describing the Sellers thread, it is said that the height of the V is divided by eight, the top eighth removed, and the groove at the bottom filled up one-eighth. This gives an idea of the shape of the thread, but it does not convey to the mind its most valuable feature, namely, the increasing of its cross-section at the base of the thread, whereby the strength of the bolt is increased from seven to twenty per cent. over the V-thread bolt.

On examining the question, I found that two-eighths of the altitude might be removed and the groove filled up two-eighths; that on a bolt one inch in diameter this would increase the strength of the bolt more than fifteen per cent. over the Sellers bolt of the same size, or thirty per cent. over the V.

I had three taps made, all of the same size, one inch in diameter, all of the same pitch, viz.: eight threads to the inch, and all having the same angle of 60°. One with the ordinary V-thread, one with the Sellers thread, and one with my experimental thread. On examining the dimensions of the different bolts, the diameters at base of the threads were found to be, respectively, ·784, ·838 and ·892; and their areas of cross-section at the base of the thread, ·4827, ·5515 and ·6249, respectively. Cutting the V-thread reduces the cross-section about thirty-eight per cent.; cutting the Sellers thread, about thirty per cent., and my experimental thread, about twenty per cent. of the full section.

The bolt having the Sellers thread is found to be fourteen per cent. stronger than the V, and my experimental bolt thirteen per cent. stronger than the Sellers, or thirty per cent. stronger than the bolt with the V-thread.

The specimens were prepared as follows: four rods, eighteen inches long, rough as they came from the mill, one and one thirty-second of an inch in diameter, and four rods turned down to one inch in diameter. These were used to test the quality of the iron.

Twelve specimens each, having the three different threads on them.

Not to trouble you with all the figures, I will say, briefly, that each specimen was broken in the small section at the bottom of the thread, with a load corresponding in almost exact proportion to its quality and cross-section. The breaking strain of the specimens averaged as follows:

Bolt having V-thread, ...	24,300 pounds.
Bolt having Sellers thread, ...	27,000 "
Bolt having my experimental thread, ...	31,600 "

As the specimens having the V-thread resisted a load fully equal to the others in proportion to size, the long-prevailing idea, that a bar of iron is weakened in excess of the reduction of its cross-section, by having a sharp groove cut into it, was thus shown to be erroneous.

The rods having the scale turned off withstood a load in a proportion of their cross-sections, equal to the rods that were not turned down. This, with the observation of other experimenters, that the scale always cracks off of the specimens as soon as the elastic limit is reached, proves that iron is no stronger with the scale on, than when it is removed.

After breaking all the specimens, it was found that not one of the nuts could be run forward a part of one thread, except on three or four of the specimens, which broke inside of the nut. Yet all of the nuts could be easily run off in the opposite direction with the thumb and finger. This proved conclusively that none of the threads were injured materially while resisting a strain that broke all the specimens.

I tested the forty-eight inch specimens for the elastic limit in the full section. All the specimens having the V-thread broke before the elastic limit was reached.

I detected it only in one specimen in the rods having the Sellers thread.

All of the specimens having my experimental thread stretched considerably before breaking.

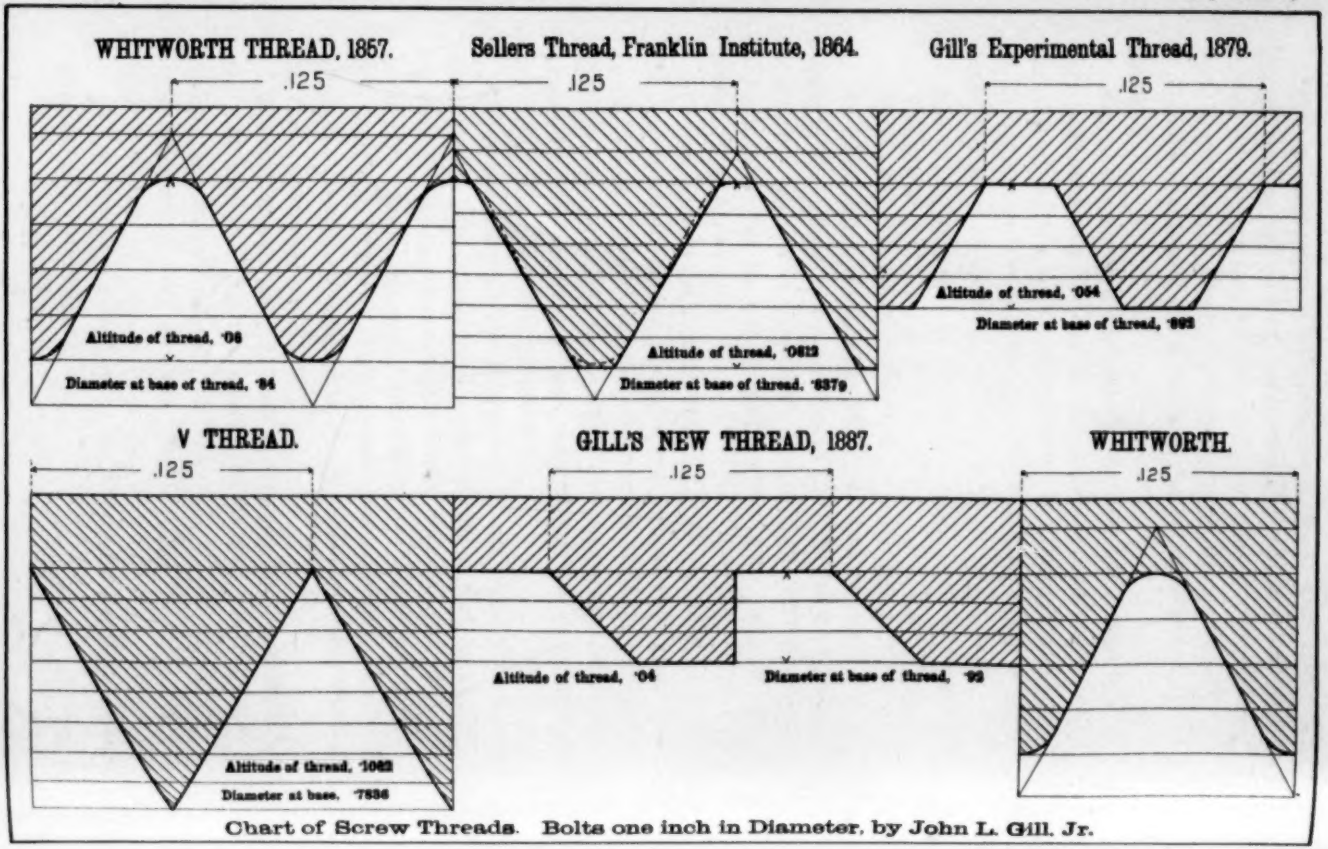


Chart of Screw Threads. Bolts one inch in Diameter, by John L. Gill, Jr.

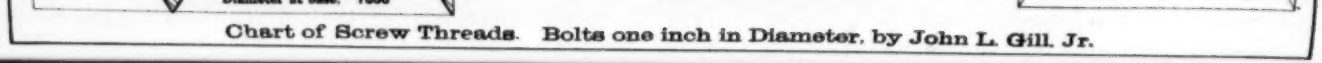
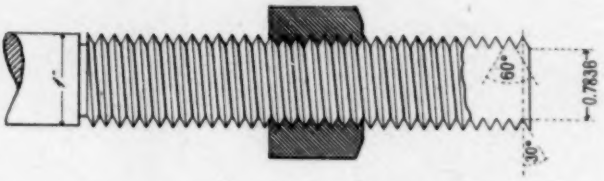


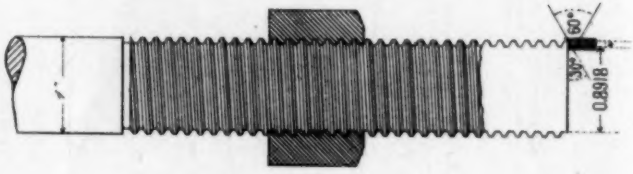
Chart of Screw Threads. Bolts one inch in Diameter. by John L. Gill. Jr.

V THREAD.

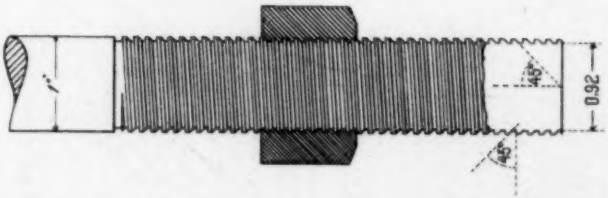


Sellers or Franklin Institute Thread, 1864.

Gill's Experimental Thread, 1879.



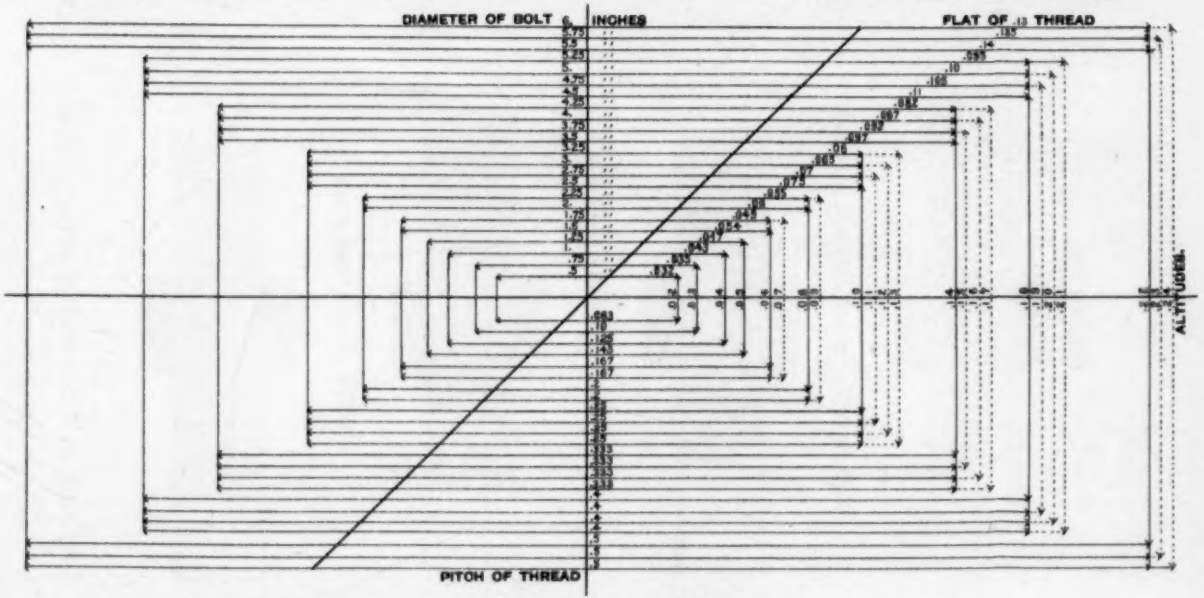
Gill's New Thread, 1887.



Screw Threads in Section by John L. Gill, Jr., June, 1887.

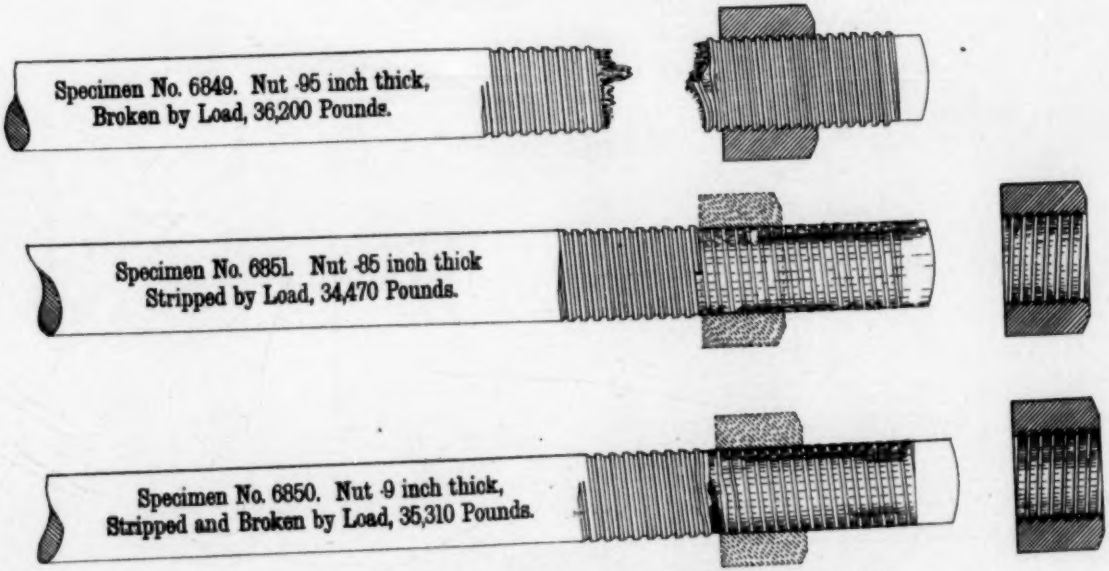
DIAGRAM:

Showing a Single Thread in a nut and on a bolt on all sizes from ⅛ inch to 6 inches in Diameter.



Used in the New System of Screw Threads, by John L. Gill, Jr.

JUNE, 1887.


Specimen No. 6849. Nut .95 inch thick,
Broken by Load, 36,200 Pounds.
Specimen No. 6851. Nut .85 inch thick
Stripped by Load, 34,470 Pounds.
Specimen No. 6850. Nut .9 inch thick,
Stripped and Broken by Load, 35,310 Pounds.

Experiments with New Thread by John L. Gill, Jr., October, 1887.

I soon observed that my experimental thread had the same objections that existed in the Sellers form of thread, namely, that the altitude of the thread was dependent on the pitch or number of threads per inch, and was necessarily divisible by the fraction to the ten-thousandth of an inch, and that the strain was applied to a surface at an angle of 120° from the axis of the bolt, having a tendency to expand or burst the nut; so I abandoned further experiments in that direction.

At a meeting of the American Institute of Mining Engineers, held at Chattanooga, in 1885, Major Wm. R. King read a paper on the subject of screw-threads, in which he took the same ground that I did, that the ordinary thread was cut too deep into the iron, and consequently the bolt was weakened more than was necessary, and he proposed to remedy the evil, by increasing the number of threads per inch, thereby reducing the depth of the thread.

The experiments of which he gave an account were very interesting and sustained his views, but the plan he adopted has the same objections that the Sellers, the Whitworth and the V-threads have, namely, the unmeasurable altitude, and the objectionable angle of 55° or 60°, whereby the strain is applied at an angle of 120° to the axis, producing a tendency to wedge through the nut when being strained.

Major King stated in his paper, that when he used eighteen threads to the inch, the thread did not strip off, but that the bolt wedged through the nut.

This is certainly an argument against increasing the number of threads, or using any form of V-thread.

Fine threads have frequently been suggested, and your committee, in 1864, gave some consideration to the question, but the many objections urged against fine threads, induced the committee to reject them.

It would be impossible for any person to design a new form of thread, for the reason that every shape of thread that could be made has been used or described.

It occurred to me that a thread formed part square and part V (such as I had used for the pulling screw in building my testing machines, and such as is used in the construction of rolling-mill housings) might be applied to an interchangeable system, suitable for bridge work and car building.

I found that a thread might be made in this way in which the altitude was not dependent upon the pitch of the thread, and that I could make the altitude in proportion to the diameter of the bolt. I further discovered that making the altitude $\frac{1}{100}$ of an inch high, for each one-fourth of an inch in diameter, would reduce the cross-section of the bolt uniformly 15·35 per cent. on all sizes, so I worked out a table of sizes from one-half inch to six inches in diameter, without reference to the pitch of the threads, and then made a diagram to determine the pitch and the angle of the receding side. It will be observed that I use the same number of threads on the smaller sizes as the Sellers, but on some sizes I use a different number.

The Sellers system has nine fractional numbers, while mine has but one. As the lathes of this country are arranged for chasing threads from one to the inch and upwards, it is desirable to avoid fractional threads.

I make the resisting side of the thread at 90° to the axis, and the receding side at an angle of 45°, the top and bottom of the threads parallel to the axis of the bolt. The flat surface is found by subtracting the altitude from the pitch, and dividing the remainder by two.

I may say here that your committee of 1864 mentioned a thread having one side at a right angle to the axis and the other side at some other angle, and stated that it would be much the strongest form of thread, but they would not recommend it because it was only applicable to bolts in which the strain was applied in one direction only.

I would ask if any one can tell me of a bolt in which the strain is applied in more than one direction? Of course, feed screws to lathes and planers and the adjusting screws of fine mechanical apparatus have to be made to work either way, but in those cases special screws are usually made.

It will be observed, on examining the table, that my system reduces the cross-section of the bolt uniformly about 15·35 per cent., while the Sellers system reduces it eighteen per cent., on a six-inch bolt, and thirty-five per cent. on a half-inch bolt, with varying proportions on the intermediate sizes; the V-thread reduces a six-inch bolt twenty-four per cent., and varying reductions on sizes down to one-half inch, at which it reaches fifty-eight

per cent. Now, if the thread on a six-inch bolt is strong enough with a reduction of eighteen per cent., why waste material by cutting away from fifteen to thirty per cent. more?

I determined to make some tests to prove my figures before I brought the table before the public. Through the courtesy of Messrs. Hoopes & Townsend, who furnished the iron and nuts for the specimens, Mr. H. R. Heyl who furnished the machine shop labor in preparing the specimens, and of Mr. Grant (who has charge of the Fairbanks testing machine) and Mr. Tinius Olsen (the manufacturer of the Olsen testing machines), who separately made the tests for me, I am prepared to present you with the results, and also to lay the specimens before you for examination.

You will observe that the iron was of a very good quality, having a breaking strength of over 53,000 pounds per square inch, with an elastic limit of from sixty-three to sixty-eight per cent. of the breaking load. It was very ductile, as is shown by the elongations averaging over twenty-one per cent. in ten inches.

Some of my hearers not familiar with the testing of iron, may be a little surprised to see so much difference in the resisting strength of the different specimens made from the same lot of material, and of the same size. These differences are not greater than are found in the best of bar iron. The differences are not so great in steel, owing to its greater homogeneity.

The nuts were from common stock and were excellent, as not one of them showed any tendency to give way in the thread.

You will notice by the table that I used six specimens of each size, one-half inch, three-fourths inch and one inch, all twenty inches long, to determine the quality of the iron.

Six specimens each size one-half inch, three-fourths inch and one inch, having the Sellers thread, and six specimens each size, one-half inch, three-fourths inch and one inch having my new thread.

The results are clearly shown forth in Tables I and II. Table III presents the results of some experiments made to determine the stripping strength of the threads, and also the strength of the nuts.

There has been a general impression that nuts the thickness of half the diameter of the bolt, would break the bolt, but I found no one that could tell me how thin a nut would have to be, before the

thread would strip, so I made these experiments to determine this question. You will see that on a one-inch bolt having the Sellers thread, a nut the thickness of four-tenths of the diameter was as likely to strip the thread on the bolt as to break the bolt.

The thread will never strip in the nut, if of a good quality, as the strain is applied across the fibre of the iron, while on the bolt it is applied lengthwise of the fibre, and the circumference at the bottom of the thread on the bolt, is much less than the circumference of the thread at the base inside of the nut.

On my bolt a nut is required to be as thick as nine-tenths of the diameter, as was shown by the experiments. At that thickness of the nut, the bolt both broke and stripped, while at ·95 the bolt broke, and at ·85 the thread stripped; so if the nuts are made of the same thickness of the diameter of the bolt, there will be a margin of eleven per cent. in favor of the bolt breaking instead of stripping.

It is apparent, from these trials, that I utilize ninety per cent. of the strength of the nut by my proportions, while the Sellers form utilizes only forty per cent. of the nut.

ANALYSIS OF TABLES 1 AND 2.

Diameter of bolts,	½ in.	¾ in.	1 in.
Area of cross-section at base of thread,	·1662	·3739	·66476
Breaking load of specimens,	10,796	23,600	42,142
Breaking load of iron, per sq. inch,	54,998	53,418	53,657
Elastic limit of iron,	6,946	12,260	26,829
Elastic limit per cent. of breaking load,	64·33 p.c.	68·89 p.c.	63·66 p.c.
Gill thread reduces cross-section of bolt by calculation in table,	15·35 p.c.	15·36 p.c.	15·35 p.c.
By actual test, by breaking load,	11·45 p.c.	13·26 p.c.	11·95 p.c.
Sellers thread reduces cross-section of bolt by calculation in table,	35·71 p.c.	31·66 p.c.	29·84 p.c.
By actual test, by breaking load,	30·16 p.c.	29·04 p.c.	30·21 p.c.
Strength of Gill bolt by calculation in pounds with iron of above strength,	9,140	19,973	35,669
By actual test,	9,560	20,471	38,142

Record of Tests Made by Mr. Grant and Tinius Olsen, to Show the Difference between the Gill and Sellers Form of Screw-Threads.

TABLE I.—*To Determine the Quality of the Iron.*

A.—½" Round Iron.					D.—¾" Round Iron.					G.—1" Round Iron.				
By whom made.	Laboratory Number.	Breaking Load in Pounds.	Elastic Limit in Pounds.	Elongation in 10 Inches.	By whom made.	Laboratory Number.	Breaking Load in Pounds.	Elastic Limit in Pounds.	Elongation in 10 Inches.	By whom made.	Laboratory Number.	Breaking Load in Pounds.	Elastic Limit in Pounds.	Elongation in 10 Inches.
G	6865	11,100	6,850	2·08	G	6860	23,470	16,800	2·52	Gill	5721	42,000	26,000	2·47
G	6942	10,645	6,400	2·02	O	5801	23,910	14,860	2·50	Grant	6846	42,565	26,500	2·50
G	6943	10,630	6,300	2·09	G	6934	23,260	16,750	2·50	G	6926	41,480	26,900	2·02
O	5808	10,800	7,100	2·12	G	6935	23,510	16,700	2·48	G	6927	42,090	27,300	2·04
O	5837	10,725	7,525	2·04	O	5829	23,750	16,250	2·41	O	5821	42,600	27,650	2·22
O	5838	10,875	7,500	2·53	O	5830	23,700	16,200	2·47	O	5822	42,120	26,625	2·17
Average, . .		10,796	6,946	2·14	Average, . .		23,600	16,260	2·48	Average, . .		42,142	26,829	2·23
Per square inch,		54,998			Per square inch,		53,418			Per square inch,		53,657		

TABLE II.—*To Determine the Strength of the Bolts.*

B.—½" Bolts.						E.—¾" Bolts.						H.—1" Bolts.					
By whom made.	Laboratory Number.	Gill Thread. Breaking Load in Pounds.	Sellers Thread. Breaking Load in Pounds.	Elongation in 10". Gill Thread.	Elongation in 10". Sellers Thread.	By whom made.	Laboratory Number.	Gill Thread. Breaking Load.	Sellers Thread. Breaking Load.	Elongation in 10". Gill Thread.	Elongation in 10". Sellers Thread.	By whom made.	Laboratory Number.	Gill Thread. Breaking Load.	Sellers Thread. Breaking Load.	Elongation in 10". Gill Thread.	Elongation in 10". Sellers Thread.
O	5809	9,975		·78		G	6939	19,925		·53		G	6931	36,270		·72	
G	6944		7,505		·0	G	6936		16,690		·23	G	6928		29,010		·30
O	5810	9,300		·61		G	6940	20,590		·54		G	6932	38,375		·80	
G	6945		7,590		·0	G	6937		16,140		·10	G	6929		28,310		·27
G	6949	9,460		·69		G	6941	20,330		·45		G	6933	38,820		·83	
G	6946		7,410		·0	G	6938		16,350		·11	G	6930		29,000		·32
O	5842	9,450		·68		O	5834	(Stripped) 20,880		·63		O	5826	38,750		·80	
O	5839		7,225		·0	O	5831		16,520		·03	O	5823		30,150		·32
O	5843	9,925		·67		O	5835	20,580		·55		O	5827	38,740		·75	
O	5840		7,630		·0	O	5832		16,875		·00	O	5824		31,250		·36
O	5844	9,250		·65		O	5836	20,525		·55		O	5828	37,900		·67	
O	5841		7,880		·0	O	5833		17,910		·28	O	5825		28,750		·28
Average, . .		9,560	7,540	·68	·0	Average, . .		20,471	16,747	·54	·12	Average, . .		38,142	29,411	·76	·31

TABLE III.—*To Determine the Stripping Strength.*

C.—½" bolts							F.—¾" bolts							I.—1" bolts.						
By whom made.	Laboratory Number.		Thickness of Nut in Inches.	Thickness per Cent. of Diameter.	Destructive Load in Pounds.	Elongation in 10 Inches.	Remarks.	By whom made.	Laboratory Number.		Thickness of Nut in Inches.	Thickness per Cent. of Diameter.	Destructive Load in Pounds.	Elongation in 10 Inches.	Remarks.	By whom made.	Laboratory Number.		Thickness of Nut in Inches.	Thickness per Cent. of Diameter.	Destructive Load in Pounds.		Remarks.
O	5809		·483	96·6	9,975	·78	Broke.									G	6848	Iron.			39,530	2·65	50·241 per □ inch.
G	6949	Gill Thread.	·47	94·	9,400	·57	Stripped.	O	5803	Gill Thread.	·75	100·	20,700	·78	Broke.	"	6849		·95	95	36,200	·8	Broke.
G	6948		·46	92·	8,685	·46	Broke.	O	5804		·7	93·	20,650	·76	S. and B.	"	6850		·90	90	35,310	·67	S. and B.
G	6947		·454	91·	8,889	·45	S. and B.	O	5805		·65	86·	21,190	·6	Stripped.	"	6851		·85	85	34,470	·6	Stripped.
O	5810		·45	90·	9,300	·61	Broke.	O	5806		6	80·	20,425	·5	"	"	6871		·8	80	35,390	·6	"
O	5811		·40	80·	8,940	·59	Stripped.	O	5807		·55	73·	21,395	·65	"	"	6872		·75	75	36,070	·76	"
O	5812		·35	70·	9,225	·55	"									Gill	5720		·8	80	32,800	—	"
O	5813		·30	60·	8,510	·48	"																
G	6866		·3	60·	7,570	·0	Broke.	G	6861		·4	53·3	16,880	·1	Broke.	"	6855		·5	·50	30,305	·3	Broke.
G	6867	Sellers Thread.	·25	50	7,055	·0	Stripped.	G	6862	Sellers Thread.	·35	46·6	16,635	·02	"	"	6856	Sellers Thread.	·475	·475	29,005	·28	"
G	6868		·2	40·	6,575	·0	"	G	6863		·3	40·	15,095	·0	Stripped.	"	6852		·45	·45	28,320	·39	"
								G	6864		·2	33·3	12,985	·0	"	"	6853		·4	·40	25,445	·27	B. and B.

G	6866	Sellers Thread.	·3	60'	7.570	·0	Broke.	G	6861	Sellers Thread.	·4	53·3	16,880	·1	Broke.	"	6855	Sellers Thread.	·5	·50	30,305	·3	Broke.
G	6867		·25	50	7,055	·0	Stripped	G	6862		·35	46·6	16,635	·02	"	"	6856		·475	·475	29,005	·28	"
G	6868		·2	40'	6,575	·0	"	G	6863		·3	40'	13,095	·0	Stripped.	"	6857		·45	·45	28,390	·39	"
								G	6864		·25	33·3	12,985	·0	"	"	6858		·4	·40	26,145	·27	" and B.

A NEW SYSTEM OF SCREW THREADS, BY JOHN L. GILL, JR.

PHILADELPHIA, PA., JUNE 1, 1887.

⅛ in.	¼ in.	⅜ in.	1 in	1⅛ in.	1¼ in.	1⅜ in.	1¼ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 in.	3¼ in.	3½ in.	3¾ in.	4 in.	4¼ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5½ in.	5¾ in.	6 in.
1'	10'	9'	8'	7'	7	6'	6'	5'	5'	4'	4'	4'	4'	3'	3'	3'	3'	2½'	2⅔'	2½'	2½'	2'	2'	2'
·091	·10	·111	·125	·143	·143	·167	·167	·2	·2	·25	·25	·25	·25	·333	·333	·333	·333	·4	·4	·4	·4	·5	·5	·5
·025	·03	·035	·04	·045	·05	·06	·07	·08	·09	·10	·11	·12	·13	·14	·15	·16	·17	·18	·19	·20	·21	·22	·23	·24
·033	·035	·038	·043	·49	·047	·054	·049	·06	·055	·075	·07	·065	·06	·097	·092	·087	·082	·11	·105	·10	·095	·14	·135	·13
·575	·69	·805	·92	1·035	1·15	1·38	1·61	1·84	2·07	2·30	2·53	2·76	2·99	3·22	3·45	3·68	3·91	4·14	4·37	4·60	4·83	5·06	5·29	5·52

OF THE V, THE FRANKLIN INSTITUTE AND A NEW SYSTEM PROPOSED, BY JOHN L. GILL, JR., WITH THEIR COMPARATIVE STRENGTHS AND VALUES.

⅛ in.	¼ in.	⅜ in.	1 in.	1⅛ in.	1¼ in	1½ in	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 in.	3¼ in	3½ in.	3¾ in.	4 in.	4¼ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5½ in.	5¾ in.	6 in.
'	10'	9'	8'	7'	7'	6'	5'	4½'	4½'	4'	4'	3½'	3½'	3¼'	3'	3'	2⅞'	2¾'	2⅝'	2½'	2½'	2⅜'	2¼'	2¼'
'	10'	9'	8'	7'	7'	6'	6'	5'	5'	4'	4'	4	4'	3'	3'	3'	3'	2½'	2½'	2½'	2½'	2'	2'	2'
·0786	·0866	·0960	·1082	·1236	·1236	·1444	·1732	·1924	·1924	·2165	·2165	·2474	·2474	·2665	·2886	·2886	·3012	·3149	·3299	·3464	·3464	·3646	·3646	·3848
·0589	·0649	·0720	·0812	·0927	·0927	·1083	·1299	·1443	·1443	·1624	·1624	·1856	·1856	·1999	·2165	·2165	·2259	·2361	·2474	·2598	·2598	·2735	·2735	·2886
·025	·03	·035	·04	·045	·05	·06	·07	·08	·09	·10	·11	·12	·13	·14	·15	·16	·17	·18	·19	·20	·21	·22	·23	·24
·0113	·0125	·0140	·0156	·018	·0180	·0210	·0250	·0280	·0280	·0310	·0310	·0357	·0357	·0384	·0410	·0410	·0435	·046	·048	·05	·05	·0526	·0526	·0555
·033	·035	·038	·043	·049	·047	·054	·049	·06	·055	·075	·07	·065	·06	·097	·092	·087	·082	·11	·105	·10	·095	·14	·135	·13
·625	·75	·875	1'	1·1250	1·25	1·50	1·75	2'	2·25	2·5	2·75	3'	3·25	3·5	3·75	4'	4·25	4·50	4·75	5'	5·25	5·50	5·75	6'
4677	·5767	·683	·7836	·8778	1·0028	1·2112	1·4036	1·6152	1·8652	2·0670	2 3170	2·5052	2·7552	2 9670	3·1728	3·4228	3·6476	3·8702	4·0902	4·3072	4·5572	4·7708	5·0208	5·2304
5072	·6201	·7310	·8376	·9396	1 0666	1·2834	1 4902	1·7114	1·9614	2·1752	2 4252	2·6288	2·8788	3 1002	3·3170	3·5567	3·7982	4·0278	4·2552	4·4804	4·7304	4·9530	5·2030	5·4228
·575	·69	·805	·92	1·035	1·15	1·38	1 61	1·84	2·07	2·30	2·53	2·76	2·99	3·22	3·45	3·68	3·91	4·14	4·37	4·60	4·83	5·06	5·29	5·52
·3068	·4418	·6013	·78539	·9940	1·2271	1·7671	2·4052	3·1416	3·9761	4·9080	5·9396	7 0686	8·2939	9 6211	11·044	12·566	14·186	15·904	17·720	19·635	21·648	23·758	25·967	28·274
1711	·2612	·3664	·4822	·6052	·7901	1·152	1·548	2·048	2·732	3·355	4·216	4·928	5·961	6·914	7·907	9·214	10·452	11·760	13·140	14·570	16·310	17·880	19·800	21·480
2029	·3019	·4197	·5510	·6934	·c908	1·2956	1·7441	2·3003	3 0215	3·7161	4·6194	5 4272	6·5070	7·5486	8·6414	9·9870	11·330	12·742	14·286	15·766	17·575	19·271	21·261	23·096
2597	·3739	·5089	.06476	·8413	1·0357	1·4957	2·036	2·659	3 3654	4·1547	5·0273	5·9847	7·0220	8·1433	9·3482	10·636	12·010	13·461	15·000	16·6192	18·322	20·109	21·979	23·931
23	40·78	38·97	38·63	39·11	35 60	34·81	35·72	34·65	31·28	31·64	28·98	30·98	28·13	28·14	28·40	26·79	26·33	26·05	25·84	25·79	24·65	24·74	23·75	24·03
61	31·66	30·20	29·84	30·24	27·40	26·71	27·52	26·71	23·97	24·25	22·20	23·26	21·58	21·55	21·63	20·52	20·09	19·93	19·75	19·73	18·83	18·76	18·12	18·33
35	15 36	15·36	15 35	15·36	15·35	15·36	15·35	15·36	15·36	15·35	15·36	15·35	15 36	15·36	15·35	15·35	15·36	15·36	15·35	15·36	15·36	15·36	15·35	15·36
58	15 59	14·54	14 27	14 57	12·73	12·41	12 59	12·40	10 65	10·76	9·55	10·06	9·12	9·46	9 28	8·52	8·42	8·25	8·22	8·16	7·72	7·77	7·37	7 49
06	23·84	21·46	20·64	21·33	16·52	15·44	16 81	15·50	11·31	11·81	8·83	10·30	8·04	7 88	8·18	6·43	6·00	5·73	5·48	5·45	4·27	4·30	3·38	3·50
79	42·76	39·13	37 86	39·01	31·37	29 77	31·52	29·83	19·51	23·84	19·23	21·40	17·78	17·77	18·22	15·50	14·91	14·45	14·15	14·07	12·32	12·47	11·01	11·26

Strength of Sellers bolt by calculation in pounds with iron of above strength, ...	6,940	16,126	29,595
By actual test, ...	7,540	16,747	29,411
Gill bolt stronger than Sellers—			
Per cent. by calculation in table, ...	31·69 p.c.	23·84 p.c.	20·63 p.c.
Per cent. stronger by actual test, by breaking load, . .	26·79 p.c.	22·24 p.c.	29·69 p.c.

EXPLANATION OF TABLES.

G stands for Grant and O for Olsen. The iron for the specimens in the Tables I, II and III, letters A, B and C, were all taken from the same bundle.

The iron used in Tables I, II and III, letters D, E and F, were all taken from the same bundle.

The iron used in Tables I and II, letters G and H, were from the same bundle, while the iron in Table III, letter I, was from another lot, at a different time, but from the same mill as the other specimens.

It was of lower tensile strength, being only 50,241 pounds per square inch, while the iron in Tables G and H averaged 53,657 pounds, its elastic limit for the specimen No. 6,848, was 25,400 pounds, while the average of the others was 26,829 pounds. The elongation in ten inches being 2·67 inches, was greater than the average of the other specimens, which was 2·23 inches in the same length. Its greater ductility is apparent.

TABLE I.

Six specimens of iron, each size one-half inch, three-fourths inch and one inch were used to test the quality of the iron.

The average strength, elastic limit, and elongation in ten inches is shown at the foot of each column.

TABLE II.

Six specimens each size one-half inch, three-fourths inch and one inch having the Gill thread; and six each size one-half inch, three-fourths inch and one inch are shown, having the Sellers thread. The columns showing the Gill threads are placed in juxtaposition with the columns showing the Sellers thread, so that an easy comparison can be made, and a correct idea formed of the comparative strength of bolts, having the different forms of threads on them.

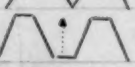
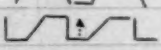
The nuts used in this table were taken from common stock, and are supposed to be in thickness the same as the diameter of the respective sizes of bolts. The nuts were not measured. Specimen No. 5,834, letter E, stripped with a load greater than was required to break any other specimen.

TABLE III.

The tests in this table were made to determine, if possible, the thickness of the nut that would be required to strip the threads instead of breaking the

1	Diameter of bolt,	½ in.	⅝ in
2	Number of threads per inch,	12°	11°
3	Pitch of threads,	·083	·09
4	Altitude of thread,	·01	·01
5	Width of flat top,	·032	·03
6	Diameter of bolt at base of thread,	·46	·57

A TABLE SHOWING THE PROPORTIONS OF SCREW THREADS O

1	Diameter of bolt,	½ in.	⅝ in.
2	Number of threads per inch, V and FRANKLIN INSTITUTE threads,	13°	11°
3	Number of threads per inch, Gill thread,	12°	11°
4	Altitude of V thread,	·0666	·078
5	Altitude of  FRANKLIN INSTITUTE thread,	·0300	·038
6	Altitude of  Gill thread,	·02	·025
7	Width of flat top of FRANKLIN INSTITUTE thread,	·0096	·011
8	Width of flat top of Gill thread,	·032	·033
9	Diameter of bolt, full section,	·5	·625
10	Diameter of bolt at base of V-thread,	·3668	·467
11	Diameter of bolt at base of FRANKLIN INSTITUTE thread,	·3993	·507
12	Diameter of bolt at base of Gill thread,	·46	·575
13	Area of cross section, original size,	·1963	·306
14	Area of cross section at base of V-thread,	·1056	·171
15	Area of cross section at base of FRANKLIN INSTITUTE thread,	·1262	·202
16	Area of cross section at base of Gill thread,	·1662	·259
17	Per cent. reduction of cross section for V-thread,	58·19	44·23
18	Per cent. reduction of cross section for FRANKLIN INSTITUTE thread,	35·71	30·61
19	Per cent. reduction of cross section for Gill thread,	15·35	15·35
20	FRANKLIN INSTITUTE bolt, per cent. stronger than V,	19·50	18·58
21	Gill bolt, per cent. stronger than FRANKLIN INSTITUTE,	31·69	23·06
22	Gill bolt, per cent. stronger than V,	57·38	51·79

.	½ in.	⅝ in.	¾ in.	⅞ in.	1 in	1⅛ in.	1¼ in.	1⅜ in.	1½ in.	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 i
.	12"	11"	10"	9"	8"	7"	7	6"	6"	5"	5"	4"	4"	4"	
.	·083	·091	·10	·111	·125	·143	·143	·167	·167	·2	·2	·25	·25	·2	
.	·02	·025	·03	·035	·04	·045	·05	·06	·07	·08	·09	·10	·11	·1	
.	·032	·033	·035	·038	·043	·49	·047	·054	·049	·06	·055	·075	·07	·0	
.	·46	·575	·69	·805	·92	1·035	1·15	1·38	1·61	1·84	2·07	2·30	2·53	2·7	

THREADS OF THE V, THE FRANKLIN INSTITUTE AND A NEW SYSTEM PROPOSED, BY J

½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in	1⅜ in	1½ in.	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 i
13"	11"	10"	9"	8"	7"	7"	6"	5"	4½"	4½"	4"	4"	3½	
12"	11"	10"	9"	8"	7"	7"	6"	6"	5"	5"	4"	4"	4	
·0666	·0786	·0866	·0960	·1082	·1236	·1236	·1444	·1732	·1924	·1924	·2165	·2165	·2	
·0500	·0589	·0649	·0720	·0812	·0927	·0927	·1083	·1299	·1443	·1443	·1624	·1624	·1	
·02	·025	·03	·035	·04	·045	·05	·06	·07	·08	·09	·10	·11	·1	
·0096	·0113	·0125	·0140	·0156	·018	·0180	·0210	·0250	·0280	0280	·0310	0310	·0	
·032	·033	·035	·038	·043	·049	·047	·054	·049	·06	·055	·075	·07	·0	
·5	·625	·75	·875	1"	1·1250	1·25	1·50	1·75	2"	2·25	2·5	2·75	3"	
·3668	·4677	·5767	·683	·7836	·8778	1·0028	1·2112	1·4036	1·6152	1·8652	2·0670	2 3170	2·5	
·3993	·5072	·6201	·7310	·8376	·9396	1 0666	1·2834	1·4902	1·7114	1·9614	2·1752	2 4252	2·6	
·46	·575	·69	·805	·92	1·035	1·15	1·38	1 61	1·84	2·07	2·30	2·53	2·7	
·1963	·3068	·4418	·6013	·78539	·9940	1·2271	1·7671	2·4052	3·1416	3·9761	4·9080	5·9396	7 0	
·1056	·1711	·2612	·3664	·4822	·6052	·7901	1·152	1·548	2·048	2·732	3·355	4·216	4 9	
·1262	·2029	·3019	·4197	·5510	·6934	·c908	1·2956	1·7441	2·3003	3 0215	3·7161	4·6194	5 4	
·1662	·2597	·3739	·5089	.66476	·8413	1·0327	1·4957	2·036	2·659	3·3654	4·1547	5·0273	5 9	
58·19	44·23	40·78	38·97	38·63	39·11	35 60	34·81	35·72	34·65	31·28	31·64	28·98	30 9	
35·71	30·61	31·66	30·20	29·84	30·24	27·40	26·71	27·52	26·71	23·97	24·25	22·20	23·2	
15·35	15·35	15 36	15·36	15 35	15·36	15·35	15·36	15·35	15·36	15·36	15·35	15·36	15·3	
19·50	18·58	15 50	14·54	14 27	14 57	12·73	12·41	12 59	12·40	10 65	10·76	9·55	10·0	
31·69	23·06	23·84	21·46	20·64	21·33	16·52	15·44	16 81	15·50	11·31	11·81	8·83	10·3	
57·38	51·79	42·76	39·13	37·86	39·01	31·37	29 77	31·52	29·83	19·51	23·84	19·23	21·4	

PHILADELPHIA, PA., JUNE 1, 1887.

.	3¼ in.	3⅓ in.	3¾ in.	4 in.	4⅓ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5⅓ in.	5¾ in.	6 in.
	4"	3"	3"	3"	3"	2½"	2½"	2½"	2½"	2"	2"	2"
	·25	·333	·333	·333	·333	·4	·4	·4	·4	·5	·5	·5
	·13	·14	·15	·16	·17	·18	·19	·20	·21	·22	·23	·24
5	·06	·097	·092	·087	·082	·11	·105	·10	·095	·14	·135	·13
	2·99	3·22	3·45	3·68	3·91	4·14	4·37	4·60	4·83	5·06	5·29	5·52

OHN L. GILL, JR., WITH THEIR COMPARATIVE STRENGTHS AND VALUES.

.	3¼ in	3⅓ in.	3¾ in.	4 in.	4¼ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5⅓ in.	5¾ in.	6 in.
	3½" 4"	3¼" 3"	3" 3"	3" 3"	2⅞" 3"	2¾" 2½"	2⅝" 2½"	2½" 2½"	2½" 2½"	2⅜" 2"	2⅜" 2"	2¼" 2"
4	·2474	·2665	·2886	·2886	·3012	·3149	·3299	·3464	·3464	·3646	·3646	·3848
6	·1856	·1999	·2165	·2165	·2259	·2361	·2474	·2598	·2598	·2735	·2735	·2886
	·13	·14	·15	·16	·17	·18	·19	·20	·21	·22	·23	·24
7	·0357 ·06	·0384 ·097	·0410 ·092	·0410 ·087	·0435 ·082	·046 ·11	·048 ·105	·05 ·10	·05 ·095	·0526 ·14	·0526 ·135	·0555 ·13
2	3·25	3 5	3 75	4·	4·25	4·50	4·75	5·	5·25	5·50	5·75	6·
8	2·7552 2·8788	2 9670 3 1002	3·1728 3·3170	3·4228 3·567	3·6476 3·7982	3·8702 4·0278	4·0902 4·2552	4·3072 4·4804	4·5572 4·7304	4·7708 4·9530	5·0208 5·2030	5·2304 5·4228
	2·99	3·22	3·45	3·68	3·91	4·14	4·37	4·60	4·83	5·06	5·29	5·52
6	8·2939	9 6211	11·044	12·566	14·186	15·904	17·720	19·635	21·648	23·758	25·967	28·274
	5·961	6·914	7·907	9·214	10·452	11·760	13·140	14·570	16·310	17·880	19·800	21·480
2	6·5070	7·5486	8·6414	9·9870	11·330	12·742	14·286	15·766	17·575	19·271	21·261	23·096
7	7·0220	8·1433	9·3482	10·636	12·010	13·461	15·000	16·6192	18·322	20·109	21·979	23·931
	28·13	28·14	28·40	26·79	26·33	26·05	25·84	25·79	24·65	24·74	23·75	24·03
	21·58	21·55	21·63	20·52	20·09	19·93	19·75	19·73	18·83	18·76	18·12	18·33
	15 36	15·36	15·35	15·35	15·36	15·36	15·35	15·36	15·36	15·36	15·35	15·30
	9·12	9·46	9·28	8·52	8·42	8·25	8·22	8·16	7·72	7·77	7·37	7 49
	8·04	7 88	8·18	6·43	6·00	5·73	5·48	5·45	4·27	4·30	3·38	3·50
	17·78	17·77	18·22	15·50	14·91	14·45	14·15	14·07	12·32	12·47	11·01	11·26

Strength of Sellers bolt by calculation in pounds with iron of above strength, ...	6,940	16,126	29,595
By actual test, ...	7,540	16,747	29,411
Gill bolt stronger than Sellers—			
Per cent. by calculation in table, ...	31·69 p.c.	23·84 p.c.	20·63 p.c.
Per cent. stronger by actual test, by breaking load, . .	26·79 p.c.	22·24 p.c.	29·69 p.c.

EXPLANATION OF TABLES.

G stands for Grant and O for Olsen. The iron for the specimens in the Tables I, II and III, letters A, B and C, were all taken from the same bundle.

The iron used in Tables I, II and III, letters D, E and F, were all taken from the same bundle.

The iron used in Tables I and II, letters G and H, were from the same bundle, while the iron in Table III, letter I, was from another lot, at a different time, but from the same mill as the other specimens.

It was of lower tensile strength, being only 50,241 pounds per square inch, while the iron in Tables G and H averaged 53,657 pounds, its elastic limit for the specimen No. 6,848, was 25,400 pounds, while the average of the others was 26,829 pounds. The elongation in ten inches being 2·67 inches, was greater than the average of the other specimens, which was 2·23 inches in the same length. Its greater ductility is apparent.

TABLE I.

Six specimens of iron, each size one-half inch, three-fourths inch and one inch were used to test the quality of the iron.

The average strength, elastic limit, and elongation in ten inches is shown at the foot of each column.

TABLE II.

Six specimens each size one-half inch, three-fourths inch and one inch having the Gill thread; and six each size one-half inch, three-fourths inch and one inch are shown, having the Sellers thread. The columns showing the Gill threads are placed in juxtaposition with the columns showing the Sellers thread, so that an easy comparison can be made, and a correct idea formed of the comparative strength of bolts, having the different forms of threads on them.

The nuts used in this table were taken from common stock, and are supposed to be in thickness the same as the diameter of the respective sizes of bolts. The nuts were not measured. Specimen No. 5,834, letter E, stripped with a load greater than was required to break any other specimen.

TABLE III.

The tests in this table were made to determine, if possible, the thickness of the nut that would be required to strip the threads instead of breaking the

bolts. The nuts were all turned down except specimen No. 5,803, shown in letter F, which was left full thickness, and placed in this table to show that one broke the bolt at a lower load than was required to strip the threads on several other specimens.

On examining Table III, it will be seen that bolts having the Sellers thread, stripped with nuts the thickness of fifty per cent. of the diameter on the one-half inch size, while on bolts three-fourths inch and one inch in diameter, stripped with nuts reduced to forty per cent. of their diameter in thickness. There was no elongation in the one-half-inch specimens, and one-tenth of one per cent. in one specimen of three-fourths inch size, and two one-hundredths in another. The one-inch specimens all showed some elongation.

The bolts having the Gill thread, in this table, showed some curious features. In Section C, one-half-inch size, a specimen with nut ·46 of an inch thick, being ninety-two per cent. of the diameter, broke at a lower load than any other specimen. Another specimen with a nut ·35 of an inch thick, being only seventy per cent. of the diameter, stripped with a load nearly equal to the average breaking load of that size.

Examining Section F, it will be seen that two specimens having nuts ·55 and ·65 of an inch thick, being respectively seventy-three per cent. and eighty-six per cent. of the diameters, stripped with a greater load than was required to break any other specimen of the same size. The iron in Section I being more ductile and of lower tensile strength than that in Sections G and H, comparisons cannot be made with each other.

In Section I, it will be observed that a bolt with a nut ·90 per cent. of the diameter, with the Gill thread, both broke and stripped; that all bolts with nuts over ·90 per cent. of the diameter thick broke, while all bolts with nuts under this thickness stripped.

One specimen with a nut ·75 of an inch thick, stripped with a load nearly equal to that required to break the strongest bolt in this series of tests.

EXPLANATION OF PLATES.

PLATE 1.

Is a chart showing the shape and relative proportions of the various forms of threads, representing the thread on a bolt one inch in diameter with eight threads to the inch.

PLATE 2.

Represents sections of bolts, with the different forms of threads having nuts in place.

PLATE 3.

Is a diagram showing the relative proportions of a single thread of the Gill form. The outside lines, forming a trapezoid at the right-hand side of the diagonal line, represent the thread on a six-inch bolt. The small trapezoid in the centre of the diagram represents the thread on a bolt one-half inch in diameter. The other trapezoids represent the threads on the varying sizes between.

The top line of each trapezoid represents the flat face at the top of the thread, the vertical lines, the altitude and resisting side of the hread. The bottom lines of the full parallelogram represent the pitch of the threads, and the diagonal line the receding side of the thread.

This diagram shows the uniform increase of one-hundredth of an inch for each one-quarter of an inch increase in diameter of bolt.

PLATE 4.

Represents three specimens described in Table 3, letter *I.* Specimen No. 6,849, with a nut the thickness of ninety-five per cent. of the diameter of the bolt, and broken by a load of 36,200 pounds.

Specimen No. 6,850 with nut ninety per cent. of the diameter in thickness broken and stripped by a load of 35,310 pounds, and specimen No. 6,851, with nut eighty-five per cent. of the diameter in thickness stripped by a load of 34,470 pounds.

HEATING CITIES BY STEAM.

BY CHARLES E. EMERY, PH.D.

[*A Lecture Delivered before the* FRANKLIN INSTITUTE, *Friday, November 18, 1887.*]

THE LECTURER was introduced by Vice-President MR. FRED. GRAFF, and spoke as follows:

Members of the INSTITUTE, *Ladies and Gentlemen:*

The advantages of a steam supply from a central station for the buildings in a city or village, and even for the detached buildings of hospitals and other public institutions in a park, are very evident, and such a system has, in the past, been many times suggested as desirable. About fifteen years ago, Birdsall Holly, of Lockport, N. Y., made experiments in his yard to show the loss of heat in transmitting steam through an underground conductor, the outcome of which was the design of a practical system adapted for street distribution, in which stuffing boxes were arranged at regular intervals of about 100 feet, and anchored fast, so as preserve their location and permit the sliding sleeves to move in and out freely, in line. Outlets were also provided in chambers back of the stuffing boxes for the attachment of service pipes to distribute the steam to buildings, so the supply was from stationary points the same as if boilers were located at such points. Simple as these improvements seem to have been, compared with previous

arrangements of interior steam piping, they form an important element of the success of modern systems of steam distribution in cities. The large steam plant of the New York Steam Company has been built up, under the direction of the writer, on the principle in the Holly patents, above described, but without the use of one of the Holly details, and the steam from boilers of 12,000 horse-power is now being delivered at a pressure of eighty pounds and upwards for power, as well as heat, through some five miles of large steam pipes, some of which extend three-fourths of a mile from the boiler station.

It is proposed to discuss the general features of what is technically called a District Steam System, and to introduce, in connection therewith, brief descriptions of the work of the New York Steam Company, illustrated by drawings of the principal details used.

A district steam plant is in some respects similar to, and at first sight would appear to be only an enlargement of, the method of distributing steam from a central point to the buildings of a large factory or public institution. In fact, however, the conditions encountered in putting pipes in streets already full of underground obstructions, such as other pipes, vaults, sewers, etc., in such a manner that consumers can be accommodated when and where desired, involve many more difficulties and require many modifications in detail, compared with a system where all the property is under one control, where space underground is rarely obstructed or valuable, and where the whole plant, with all its ramifications, may be laid out before the work is commenced.

The nature of the difficulties encountered in transmitting steam for a considerable distance are not generally understood. Condensation necessarily takes place, as is expected, but non-conductors may be applied to reduce this loss to so small a proportion of the carrying capacity of the pipes that it will not form a serious disadvantage in a mere commercial sense. The problem may be called difficult on account of the number of principles involved and the mass of engineering and mechanical details required to apply the principles correctly and successfully. Condensation is but one of the many conditions to be provided for, and in some respects an embarrassing one, but it can be satisfactorily dealt with much more readily than several others.

Dry or saturated steam is well adapted for transmission to a distance, for the simple reason that the temperature always corresponds to the pressure. The laws of thermodynamics show that absolute temperatures and pressures always bear a constant relation. It follows, therefore, that steam of a given pressure is as valuable at the distance of a mile or more from the boiler in which it is generated, as it is at the boiler itself; also that steam mixed with water, has, when the water is removed, all the properties, and is equally valuable as any other steam of the same pressure. In short, steam does not *deteriorate* the least in transmission, so long as it is steam; that is, has been freed of the water of condensation incident to its transmission. Pressure may be lost, but permit me to repeat, that the steam is as valuable as any steam of the same pressure. The problem of separating steam from water is well understood. Evidently if a mixture of steam and water be passed through a drum as large as the steam space of the boiler in which the same quantity of steam would ordinarily be generated, the water will be separated by gravity, the same as in the boiler itself. In most cases the pipes themselves act as drums. In any case, by a proper application of principles, it is possible to transmit steam to as great distances as any other fluid. The actual maximum distance must be governed by commercial considerations as to relative cost of piping and stations. To make steam efficient then, it is necessary only to maintain the desired pressure at the ends of the lines, and this depends upon the size of the pipes and the loss of pressure that can be permitted.

The first problem in designing a steam plant is to ascertain the total quantity of steam required and the quantity necessary to supply in detail the several blocks on each of the streets through which the pipes are to be run. In New York this was approximately obtained, first, by collecting the statistics on file in the Police Department, with relation to the steam boilers in place in the city, rules being given the computers by which the approximate power of a boiler could be determined from the external dimensions and type, which were the only dimensions taken by the boiler inspectors and reported to the Police Department. The aggregate cubic capacity of all the buildings within the areas

which it was expected to heat were also computed approximately from the insurance maps, and this multiplied by a proper factor gave the estimated quantity of steam required to heat that space. This preliminary work, although simple in its character, involved a great deal of labor, on account of the number of streets, buildings and boilers to be considered.

The first station of the company was located on Greenwich Street, between Dey and Cortlandt Streets. The building was designed to contain 16,000 horse-power of boilers of the Babcock and Wilcox type, and will be illustrated and explained hereafter.

In all, properties were purchased for ten stations in different parts of the city, but of these but two have as yet been constructed, viz., the one mentioned at Cortlandt and Greenwich Streets, designated as Station "B," and an inside or temporary one at Fifty-eighth Street and Madison Avenue.

Some idea of the magnitude of the work can be obtained from the statement that there are already in position in the first station one sixteen-inch pipe, one fifteen-inch pipe and one eleven-inch pipe, with only part of the capacity of the building yet utilized, and that it expected to put in in addition one thirty-inch pipe to keep up the pressure at a distance as the demand increases.

Considerable investigation was made to ascertain the proper formula for determining the sizes of pipes required to transmit the steam. The difficulty was not so much in finding formula as to decide which were best applicable. As is generally the case, the simplest was finally determined upon, based directly upon the laws of falling bodies, and in form, that generally used for the flow of water in pipes, simply substituting for the density of water that of steam at the pressure to be carried. Most of the experiments on the flow of gaseous fluids given in the text-books refer to air at low pressures and with very small quantities of discharge. There were, however, some experiments on the flow of compressed air in the pipes supplying the drills in the Mont Cenis Tunnel, where the pressure and quantity of air moved were sufficient to compare favorably with the conditions under which steam was to be transmitted. By substituting numerical values determined from these experiments in the ordinary water formula with a character representing the density introduced, a general formula was obtained in which the constant very curiously and satisfactorily coincided very

closely with those given by Wiesbach, in relation to the flow of air at about the same velocity as was expected in the steam pipes. It should be observed that the loss of pressure due to transmission varies also with the density of steam, so that any formula founded on a constant density is not precisely correct. As, however, the loss of pressure was to be restricted to ten pounds, the original formulæ were based on the average density. At a later date, however, investigations were made in which the variations in pressure were taken into consideration; the formula derived from the water formula being considered a differential formula with relation to the flow of steam. By this means a formula was obtained which, it was believed, well represented the probable facts for all steam pressures, and all losses of pressure in transmission. Between the limits of pressure it was expected to use in practice, it was found that practically one formula was as exact as the other, so the use of the simpler one was continued for general use. When the slope was introduced in the formula, to wit, ten pounds per one-half mile, and the density which was first fixed at that due to seventy pounds, with the expectation of going from seventy-five pounds down to sixty-five, the formula for the weight of steam discharged per hour reduced at once to

$$W = 87{\cdot}3\, d^{\frac{5}{2}};$$

d, being the inside diameter of pipe in inches.

This form results from the fact that the areas of the pipes vary as the squares of their diameters, and the hydraulic mean depths which are proportioned to the friction as the square roots of the diameters, so the products of the two vary as the $\frac{5}{2}$ power. For strict accuracy some modifications should have been introduced in the formula, as the friction undoubtedly reduces as the velocity increases, and it is probable also that the friction reduces faster than the hydraulic mean depth. It was not necessary to consider these points, however, as the variation in velocity and density were so small. In practice it was not found expedient to reduce the pipes as rapidly as the mere conditions of demand, according to the maps above referred to, would indicate. It was thought that possibly there might be a concentration of demand on certain lines, and it was also desirable to make provision f r reinforcing the pipes near their ends from other

stations should it become necessary. Consequently, in practice, only the lines leading to the boiler house were proportioned by the rule, and the others as a general thing were made larger. It was not thought best in the down-town streets to lay any steam pipe less than six inches in diameter throughout the length of a long block, and although this was small by calculation for some blocks, still as it could be fed at both ends, it was considered sufficient, and has since so proved in practice. The above formula was designed to carry the whole capacity of the pipe to its end, whereas in practice steam is being continually drawn off, thereby enabling the remaining quantities of steam to be carried along with less relative reduction of pressure. On the whole, therefore, considering the various conditions, it was decided to increase the value of the constant in the formula to an even 100, and the table of the carrying capacity of pipes now used is simply derived by raising the actual internal diameter of the various nominal sizes of pipe in inches to the $\frac{5}{2}$ power, and carrying the decimal point two places to the right.

It is found in practice that steam pipes can be so protected that the loss of condensation will be a very small proportion of their carrying capacity. Experiments were made before the plant of the New York Steam Company was built, which showed that mineral wool, of ordinary quality, furnished very nearly the same resistance to the passage of heat as the same thickness of hair felt, and that the better qualities were equal or even superior in this respect to hair felt. As mineral wool is non-combustible, quite permanent when kept dry and not subject to friction, and withal could be manufactured quite cheaply, it was fixed upon as the material to insulate the pipes of the New York Steam Company. In a majority of cases the pipes were suitably supported in the bottom of a trench, brick walls built up at either side, and covered with planking and roofing material, as will be illustrated hereafter, so as to leave a space of from three to four inches about the pipe on all sides, in which mineral wool was placed in bulk. In some cases the wool was placed inside of wood casing of pump logs, but this was not considered a part of the regular system, and has not proved as desirable or durable as the other plan. The result of this method of covering has been that with nearly five miles of large pipes, also about two miles of smaller pipes used as

services, all under steam continuously, days, nights and Sundays, there was required but 150 horse-power each of thirty pounds of water per hour, to supply the condensation in the mains. The mains vary from sixteen inches in diameter to six inches, and the services are mostly three inches in diameter. This loss is so small, as has been previously stated, that it does not affect seriously the commercial problem of the transmission of steam. The water of condensation, however, though limited in quantity, must be properly provided for. If in all cases steam could be transmitted at slow velocities in a large pipe, graded so as to have a slight descent *away from* the source of supply, the water in the steam would separate by gravity, and trickle along the bottom of the pipe, the size of the stream of water gradually increasing until means were provided to permit its escape. By taking the stream from the top of such a pipe and arranging to blow out the water at intervals from the bottom, the length of the pipe could be continued indefinitely, no inconvenience would result, except the loss of pressure due to the distance, and the steam at any point would be as dry as though it came from the boiler direct. This ideal state of facts is accomplished as nearly as possible in practice. Steam must at times be carried up a slope instead of down, and frequently the pipes must have undulating grades to correspond substantially with those of the surface of the ground. When the movement is up a slope, the water of condensation is, to a greater or less extent, entrained by the current of steam. This is particularly the case when the steam is moving at a high velocity. In practice the up grades, in the direction the steam is transmitted, are made as sharp and as short as possible, and beyond the summits, the down grades, in which there is a natural separation of the steam and water, are made easy and long. This desirable arrangement cannot always be carried out; the street obstructions are frequently so arranged that the pipe can only be laid in undulating grades corresponding more or less to those of the surface. In all cases, arrangements are made to trap out the water of condensation at the bottom of every dip of the pipes, so that the current of steam passing onward and upward has no more water to contend with than is condensed in the portion of the pipe to be passed over. The water is removed automatically by a steam trap, and returned to the boiler house through another system of pipes, called return water pipes, the

details of which, as well as of the traps, will be referred to hereafter.

The expansion of small pipes is generally provided for by means of bends and offsets, which will spring sufficiently. This method, in its simpler form, is applicable to short lengths only, but if the arrangement be well studied, pipes of any length may be laid on this system. For instance, if it be desired to run a pipe from one end of a long building to another, it may be accomplished by crossing and recrossing a sufficient number of times. No known rules for this kind of work are formulated. The workman is supposed to make the offsets of such a number and with such lateral lengths that expansion will not strain the joints. Frequently, however, insufficient attention is given to this matter, and leaks are developed at important fittings, which it seems impossible to keep in repair, and the work can only be made satisfactory by changing the system to suit the actual conditions. A modification of the offset system with what are called swinging elbows forms a much safer method of providing for expansion, but is less used, as more fittings are required, and some little study is necessary to adopt the work to the straight lines and flat grades necessary in a building. It is, however, a very desirable way of laying long pipes of limited size underground and elsewhere, where the grade can be changed as required.

Swinging elbows are also used to pass obstructions, such as cross pipes, which can be inclosed in a yoke in the steam pipe. The steam takes the upper part of the yoke, the water of condensation the lower, and drainage is not interfered with.

Stuffing boxes or slip joints are frequently used on long lengths of pipe to provide for expansion, though generally on large pipes only. This system answers very well for water pipes, or where the steam pressure is low. With high pressures, the packing has to be very compact to resist the pressure, and great care and some considerable expense are required to keep the stuffing boxes in order and prevent them from leaking. Frequently stuffing boxes are applied without due care in anchoring the pipe. Cases have occurred where pipes were prevented from sliding simply by a lateral connection coming in contact with the side of an opening in a wall or partition. In laying a number of stuffing boxes on a length of pipe without anchorages, the whole pipe may shift to

the box which is loosest, and the others may not move at all until the first has a very extreme movement, or, as has sometimes happened, is pushed entirely in. Sometimes, in cooling such a system, the sleeve of one stuffing box is pulled entirely out of the packing.

The original street system of Birdsall Holly, who used anchored service stuffing boxes at frequent intervals, has already been referred to. The value of his system is best exemplified by briefly describing a modification of it used by a company in the city of New York, started in opposition to the work of the New York Steam Company, soon after the latter was well under way.

In the case referred to, stuffing boxes were used, but they were located only at the corners of the streets in castings, which also served as crosses to connect with the main street laterals. The consequence was that expansion had to take place for the whole length of the block, and this system was carried out whether the blocks were 100 feet long or 400 feet. The pipes were carried on rollers, so that they would move freely. If mere expansion and contraction had been all that was to be provided for, the system would have worked well enough, if properly constructed. In all cases, however, in street work, the grade and line must be changed at intervals to avoid obstructions. These were overcome in this particular case, even for pipes eight inches in diameter, by making rigid offsets, sometimes of several feet, with common screw elbows. The friction of the stuffing boxes was so great that leaks soon developed in the elbows of these offsets, and in one or two cases the elbows actually broke, letting the steam freely into the ground, and causing what were termed explosions. Moreover, the pipes, which were supposed to be nearly straight, did not always move freely in the stuffing boxes, from the great difficulty in setting the stuffing boxes exactly in line with the pipe. It was very difficult to keep the stuffing boxes tight, and the man-holes in which they were located were so hot that the men became exhausted in attempting to attend to the packing. In this system the services were taken from independent pipes anchored only at the street corners, and running for the length of the block, it being expected that there would be spring enough in the various laterals entering the house to allow for the expansion due to the length of half a block. As, however, some of the blocks were very long, it became necessary to leave considerable space in the boxing around the lat-

eral pipes, particularly near the centres of the blocks. During the early part of the work, when steam was turned on and off frequently, the fitters would sometimes allow for expansion one way and sometimes the other. They were at first accustomed to allow for a movement of the pipes from the nearest street corner as it was heated up. When the pipes were already heated, they thoughtlessly, at times, left the room on the same side, for which reason, when the pipe was shut off, the contraction would cause the service to strike the boxing, which produced leaks, and, in some cases, rupture.

In one case, where connections had been made when the pipe was heated, the service was sheared off as the pipe cooled off, which was not known until steam was again turned on, when the lampblack used for insulation was blown all over the building. In one case of this kind, a break occurred on shutting the pipe off, and in repairing the break, the fitter allowed for contraction instead of expansion, without noting that the pipe he connected to was then cold, and the same service pipe was broken a second time when the street pipe was again heated. The wisdom of Holly in arranging that the fitters should only have distances of half a hundred feet to provide for by offsets, instead of half a block, could not be more forcibly illustrated. It is almost needless to say that the system, in which the stuffing boxes were placed only at the street corners, proved an utter failure, and its operation was discontinued after a few months' trial.

When the speaker was called upon to design a steam system, it appeared to him very desirable to avoid the necessity of using slip joints, with their leaks and expense in care and attention, and it was readily seen that an elaborate system of offsets was not practicable. Experiments were, therefore, commenced with modifications of what are known as diaphragm joints, in which two annular discs of metal are bolted together through a separating ring at their outer edges, and the inner edges bolted to the ends of the lengths of pipe, or a single disc is bolted at the periphery to a large chamber connected with the pipe on one side, and the centre of the disc to the pipe on the other. With these joints, the elasticity of the disc permits limited expansion; the movement causing the discs to be dished one way or the other, as may be arranged. All these devices, when made as ordinarily proportioned, proved too stiff, and had too limited a range for use in a street system.

A trial was made with cast-iron pipe, cast very thin and corrugated very deeply, it being hoped that each pipe could be corrugated sufficiently safely to provide for the expansion of its own length. In such case it was proposed to put in a lining of thin iron to form a smooth passage for the steam. These experiments made it doubtful if the plan would succeed, even if the pipes were corrugated the entire length. Although the cast iron was elastic within a certain limit, the great difficulties in obtaining uniform thicknesses made breaks liable to occur unexpectedly. Experiments with several plates held at the inner and outer edges were more satisfactory, but as ordinarily proportioned were too stiff, and had too little range of movement for the purpose. If the discs were originally dished in one direction with a view of forcing them first flat and then to dish them in the other by pressure, they were, of course, very much stiffer. Improvements were made by reducing the thickness of the plates and corrugating them annularly, but even when the plates were made of soft steel corrugated annularly as aforesaid, and six inches free space left between the inner and outer flanges, the plates still proved too stiff, so that there was danger of breaking the joints on the pipes to move the expansion joints, and it was not thought practicable to use more than half an inch movement for each of such diaphragms. Diaphragms of this kind were actually dished from one-half inch in one direction to one-half inch in the other, making a movement of one inch, but some parts of the disc developed a tendency to stiffen sooner than the rest, and the movement could not be made back and forth a number of times without disturbing the symmetry of the disc. The improvement due to reducing the thickness was, however, so great that the suggestion came to mind that if the plates could be still further reduced with safety, the available deflection would be inversely as the cube of the thickness, and sufficient movement could be obtained.

A successful expansion joint was finally made by using discs of copper less than one-sixteenth inch thick (0·04 being finally settled upon), corrugated concentrically and supported on radial backing plates, which prevented the diaphragm from being distended, to rupture by the pressure.

Elaborate drawings of this device are shown upon the screen; one, called a double variator, having two diaphragms and providing for expansion from two fixed points on either side fifty feet away; the other, called a single variator, having but one diaphragm, and providing for expansion from one direction only. The services are taken from the bodies of these variators. The outlets are provided with flanges, but are plugged in the first instance, these plugs being removed as required with steam pressure in the mains by bolting a valve to the flange and removing the plug through it, by means of a special tool seen on the screen. The stems of the valves are extended to the surface of the street, and may be operated through suitable openings in castings placed between the paving stones. At regular intervals of about fifty feet the pipes are connected by means of ball joints, which enable the direction to be changed slightly and take out the strain. Both the ball and plain joint flanges are made tight by the use of gaskets of thin copper corrugated annularly, which squeeze into every irregularity of the surface and become absolutely tight, even without the use of paint or putty. Pipes of six inches in diameter or less are screwed into the fittings. Larger pipes (and some have been used as large as sixteen inches in diameter) are rolled into the flanges and fittings with an expanding tool. The ends of the pipes abut against shoulders, and the faces against which the expansion takes place are slightly dovetailed. The variators are provided with boxes, which cover the connecting flanges and terminate in cylinders of metal, which are built in the brick work surrounding the variators. A number of illustrations are shown of the various crosses, tees, and other special fittings required, which are necessarily made of a substantial character to resist permanently the steam pressure of eighty pounds. The bodies of the crosses and tees are made globular, to better resist the strains to which they are subjected. Wherever a valve is placed in the pipe, or a line is terminated, heavy anchorage castings are abutted against the flanges in the pipes, and masonry built against the castings with wings well spread out, to engage with as much of the surrounding soil as possible, and thereby hold the pipes and fittings rigidly in position. Two lines of mains were run originally, one for steam, the other for the return water of condensation. Generally the latter main is laid lower than the other, so that

the outlets of the two mains will pass each other. On Fifth Avenue, where there is rock excavation, with large water pipes lying at one side, the bottoms of both mains are put on a level, and the side outlets take out below the level of the mains, through what are called "drop crosses."

The traps used by the New York Steam Company are seen on the screen. They are of the bucket variety, with valves of different kinds, according to the size, operated directly by a float, or through the intervention of levers. Two forms of regulating valve were described. In one, the Curtis valve, the reduced pressure operates upon a diaphragm, which through a secondary valve admits steam to a piston operating the main valve. Another valve is shown in which the reduced pressure acts directly upon a piston connected with the valves and balanced by external weights or springs.

Considerable investigation has been necessary to perfect a meter which would answer all the conditions to be fulfilled in measuring steam. It is evident that if a displacement meter were used, the cylinder development would necessarily equal the piston development, calculated to the points of cut-off of the engines supplied through it. For ordinary slide valve engines, therefore, the meters would have to be practically as large as the engines, or run at very much higher speeds, subject to all the difficulties incident to so doing. A small three-cylinder engine has been developed for use where very small quantities of steam are required, it being expected to pass the steam at full pressure through the meter, and then reduce the pressure afterward, thus measuring only at the greatest density and the smallest volume. The conditions of use in the district now supplied require, however, another form, yet to be described.

Experiments have been made with meters of the velocimeter type, in which the velocity of the current of steam is registered by a series of indices. Mr. Birdsall Holly designed an instrument of this kind, in which the current of steam struck one edge of a series of floats, like those of a paddle wheel. The jet was controlled by a clapper falling by gravity to reduce the opening to a narrow slit, through which steam passed to strike the wheel, when the quantity of steam passing through was limited. The axis of the paddle wheel was made vertical, and upon the lower end of the shaft was a resistance paddle wheel, which worked in water of condensation

collected in the bottom of the case. The steam escaped freely from an opening between the two wheels. This meter has precisely the same kind of variations as any other velocimeter. When passing small quantities of fluid, the slip is very large, and the record is against the supply company. For quantities which may be called moderate to considerable, relative to the size of meter, the rate is remarkably near uniform, when everything is in order. When run to the full capacity of the pipe, the meters are not so accurate. The difficulty with this class of meters lies in keeping the friction constant and preventing wear. There must be some means of carrying the motion of the paddle wheel outside of the case. This is done by driving the axle, which passes through the stuffing box, at reduced speed, by means of gearing inside the case. Notwithstanding this, however, the stuffing box soon gets leaky. The speed of the wheel is quite high, and the bearings wear down rapidly, so that it can safely be stated that the apparatus is not a desirable one for use, except at comparatively low pressures and moderate velocities.

The speaker, at an early date, made up his mind that a successful meter must be based on the principle of flow through an orifice of known size, and with a known loss of head or difference of pressure. Several methods of doing this were tested. In the meter finally adopted, called a "rate meter," the steam flows through rectangular openings, governed by a valve, operated by a weighted piston, balanced on the difference of pressure between the incoming and outgoing steam, the effect of which is that the steam flows through the orifice at a constant difference of pressure. The size of the orifice is regularly registered on a broad paper strip, traversed by clockwork. The result is a diagram showing at any time in the day the quantity of steam used at that time, and the total quantity may be obtained by integrating the chart. When steam is not used, the movable pencil runs on the same line with a stationary one. The paper upon which the meter record is made is printed in divisions of one-half an inch, numbered from one to twenty-four consecutively, to represent the hours of the day, and in starting the paper, the proper division is set at the corresponding time. The time that steam is turned on is shown by the vertical line made by the movable pencil at the beginning of the diagram, and when it is shut off by a similar line at the end; and

evidently the periods when any particular change is made in the quantity of steam used can be determined from the meter diagrams, as well as the quantity used during the intervals. It was at first considered unfortunate that a reliable meter could not be obtained, which, like a water meter, would show by differences of reading the quantity of steam used for the interval between observations directly without calculation, and without the expense of maintaining a time register at each location, and of integrating the charts afterward. This system, however, proved a blessing in disguise. The greatest difficulty in settling with consumers lies in the fact that employés waste the steam. This is particularly the case during the heating season, when steam for various uses is left on continuously during nights and Sundays, thus increasing the time of consumption from, say, sixty hours a week to 168 hours. In many cases, too, the rate of consumption keeps uniform during the night as well as during the day, so that it is an easy matter to more than double the bills. The consumers at first naturally lay the blame to the steam of the steam company, but the meter charts have been the means of enabling the company to satisfy consumers when, and to what extent, the increased bills were due to mismanagement on their premises.

The meters and regulating valves are placed in the pipes leading from the streets to the building, and arranged with shut-off and pass-by valves, so that any part of the apparatus may be put in order without stopping the supply of steam to the building.

[The lecturer then described a watchman's tell-tale system, in which a valve in the pipe leading to the consumer was connected electrically with a watchman's box on the exterior of the building.]

The watchman, being provided with a suitable recording apparatus on his person, visited the several boxes in succession, and by sending an electrical impulse from a portable battery through the watchman's box into the valve, received in turn a record which could be interpreted at the office to show whether or not the valve was open. This apparatus was used while suitable meters were being devised and perfected. [Plans were also shown of the Station "B" boiler house of the company.] At that station it was necessary to erect boilers of 16,000 horse-power on an irregularly shaped plot, seventy-five feet in width, and on an average less than 120 feet deep. To obtain proper floor room, the boilers

were arranged in four tiers, each tier in a separate story twenty feet high, besides which the plans provide for a fifth story for coal storage and a basement for miscellaneous uses. Each floor is arranged for sixteen boilers of 250 horse-power each, which are placed in two rows, to face a central fire room. There are two chimneys, located between the boilers on the sides of the fire room, as near the centre of the building as the shape of the plot permitted.

The whole capacity of the building not being needed at first, the walls were only carried up to an elevation of eighty-eight feet eight inches, and a temporary roof applied, so that at present there are available only three stories for boilers, and one above for coal storage. The south chimney has been practically completed. The north one was originally extended just above the temporary roof, covered and connected with the other by a sheet-iron casing. In the summer of 1885, it was thought desirable to examine the interior of the south chimney and make any necessary repairs to lining, etc., for which reason it was decided to top out the north chimney with a shaft of practically half the area, which would be sufficient for summer use, while the other chimney was being examined.

There are now in place in the building, and fully connected, forty-eight boilers, aggregating 12,000 horse-power.

Customers were first supplied with steam in April, 1882, since which time the steam pressure has been maintained continuously day and night. The coal is brought from the dock in carts and wagons, and dumped from the rear street into small cars in the basement of the rear buildings. These cars are run back to the elevators, lifted to the top of the main building, run out on tracks over coal bins and dumped, the coal descending by gravity through chutes in front of each alternate column, and flowing out as needed on the several fire-room floors, close alongside the fronts of the boilers. The ashes pass from the ash pans down chutes in front of intermediate columns to cars in the basement. These cars are hoisted on the elevator to the roof of the rear building, run out on tracks to the front of that building, and the ashes dumped into a chute, from which they are loaded into carts on the street below.

The boilers are of the sectional type, manufactured by the Babcock & Wilcox Company.

From lack of room, a well-established rule was necessarily disregarded, and the lower portions of the chimneys, instead of being independent, were made part of the building, the section of each being rectangular and corresponding closely to the floor space occupied by one of the boilers. Within the building, the outside of the chimney walls are vertical, the offsets due to reducing the thickness of walls upward being inside the flue. Above the roof the inside of flue is parallel, and the walls are decreased on the outside, each offset being marked by a belt of granite blocks, forming a water table.

The lining extends only to the roof line, and is put in in sections, supported on the internal offsets. The lower part of each chimney above the footings is 32 feet long outside and 13 feet wide. The flue at the top is 27 feet 10 inches long and 8 feet 4 inches wide. The chimneys are topped out at a height of 220 feet above high water, or 221 feet above their foundations. The tops of chimneys are, therefore, 201 feet above the grates of the lower tier of boilers, but only 141 feet above the grates of the upper tier of boilers.

The foundations of the walls of the building are at the elevation of mean high water, and the chimney and column foundations one foot below. An archway is provided through the base of each chimney, as a means of communication between different parts of the basement.

A fixed iron ladder is attached to each chimney, and connected at top with points and at bottom with a cable to form a lightning protector. It was designed to make the top of the south chimney with a projecting platform and iron reticulated balustrade, in which case the chimney would have been 232 feet above high water. It was hoped that by painting the balustrade prominently, it would give the effect of a capital to the shaft without the weight of actual surface projections. For various reasons, however, the top was finished with a granite coping at the elevation of 220 feet above high water, as previously stated, a simple footboard being provided about the chimney, with an iron hand-rail secured in coping stones.

Although the chimney appears slender the narrow way, it is so supported as to have ample weight to resist the overturning moment caused by a wind pressure of fifty pounds per square foot on the area of one flat side.

The shaft erected on the rectangular stump of the north chimney is octagonal in section, with one edge resting on a partition wall built in the centre of the lower flue. The walls are reduced from the outside, with a stone water table at each offset. This chimney is provided with a cap constructed of wrought-iron plates, supported on cast-iron ribs built in the brick-work.

Main steam pipes, sixteen inches in diameter, are arranged in front of each row of boilers on each floor, and connected to two vertical drums, which are in turn connected in the basement to the street mains. By properly adjusting the valves provided, either set of boilers can be connected with or disconnected from either drum. The two drums on each Babcock & Wilcox boiler are yoked together near the rear of the boiler, and from the yoke a wrought-iron pipe is carried nearly to the main pipe in front, but at a lower elevation, where it connects with a copper pipe nearly parallel with the main pipe about eight feet long, which latter connects with a combined stop and check valve on the main. This bent pipe enables the main connection from the boiler to expand freely. The valve at the connection to the main is a simple metal check, which the steam is obliged to raise in order to reach the main pipe, there being provided, however, a screw from the top which can be set down to hold the check in place and make it a stop valve. When the boiler is in use, the screw is run up, and the steam passes out through the check. This arrangement has the advantage that if any rupture occurs in one boiler, the steam and water only from that one boiler will be blown out, the check valve preventing the steam in the main pipe from entering. In one case, by carelessness, water was allowed to get low in one boiler, and one of the headers was cracked. Through the crack water issued on the fire, suddenly generating a current of steam sufficient to blow the door open and force part of the fire out upon the floor. The steam and water practically put the fire out; the other boilers supplied the demand, so that there was no fluctuation in pressure observable on the recording gauge, nobody was hurt, and if there had been no person in the building, the boiler would have taken care of itself without doing injury of any kind whatever. It will be seen that had even this slight accident occurred with all the boilers in free communication, there would probably have been so much steam in the room that the stop

valve could not have been shut until the steam pressure had dropped, and the consumers of the company been greatly annoyed.

The two drums enable steam to be taken to the street by two routes, so that leaks on either can be repaired during the night without interrupting the supply to the streets. This system of duplication was so important that what is called a donkey system was also put in; that is, there is another system of steam pipes extended around behind the boilers with a small connection from each. These pipes have two connections independent of the drums, to the main street pipes in front, and one section is connected to one of the drums.

The principal cause of accidents in the operation of large, long steam pipes, underground or otherwise, arises from collections of water in the mains, when the pipes are cold or there is no steam circulating. The system previously described, of draining the mains to low points, where the water is removed automatically by steam traps, in connection with the plan of maintaining the pressure continuously, absolutely prevents any serious accumulations of water in the mains of the New York Steam Company, when the same are in use. If, however, a main be shut off for making a large connection not originally provided for, for repairs, or any other reason, intelligent care must be taken in restoring the pressure to prevent the pipes from being injured by what are termed "water-rams." Any main which has been out of use for a considerable time is liable to have water in it from the leakage of steam past the connecting valves, and its condensation in the disused pipe. Again, when the main is shut off temporarily, water is likely to be introduced from the return mains through the service connections, particularly in winter, when the heating systems are connected. Check valves are put in the discharges of the traps to prevent this, but they are not always in order. To prevent the possibility of any water entering the steam main in this way, orders are given to shut off all the service connections before shutting off a main.

If steam be admitted at the top of a vessel partially filled with cold water, condensation will take place until the surface is somewhat heated, and this in connection with a cloud which forms above the surface will retard rapid condensation, so that in due

time the full steam pressure can be maintained above water cold at the bottom. This phenomenon is not an infrequent occurrence in boilers in which the circulation is defective. It is therefore perfectly safe to heat up any vessel containing cold water, if the steam can be admitted from the top upon the surface of the water and so maintained. If, however, steam be blown in below the surface of the water, a bubble will be formed, which will increase in size until its surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow, forming what is called a water ram. In blowing a small quantity of steam into a large quantity of water, these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble as previously stated, and when condensation takes place, the water below the bubble will rush up to fill the vacuum, giving a blow directly against the side of the pipe. As the water still further recedes, the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water, which is forced forward by the incoming steam to fill the vacuum.

The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks and sometimes rupture the pipe or break out the end connections. It is not necessary, either, that the end of the pipe be closed. In fact, under certain conditions, a more forcible blow is struck when the end of the pipe is open, as, for instance, when a pipe crowned upward is filled with water, one end being open and the steam introduced at the other, a bubble will in due time be formed at the

top of crown, when the water will be forced in by atmospheric pressure from one end, and by steam pressure from the other, and the meeting of the two columns frequently ruptures the pipe. Evidently, too, the same action can occur without difficulty in a level pipe, but, as previously stated, cannot in a pipe which descends away from the entering steam, so that the latter is *always above* the water.

It is evident from the above that it is always desirable in turning steam on an inclined main to introduce it from the top and let the water out at the bottom of the slope. When this can be done, any workman can be trusted to attend to it. Frequently, however, there are undulations in the pipe, and at times mains which may contain water have to be heated by letting the steam in at the lower end. In buildings, the difficulty can, of course, be prevented by opening drip pipes at the lower end, and letting the water out before the steam is admitted. The same thing can be done with underground pipes, and provision for this should always form part of the plans when it is known that a pipe will have to be heated up in this way. In practice, however, a street system contains so very many absolutely necessary details, that a provision of this kind will not be originally provided for, and at times it will occur that a main which it was expected to heat from the top of a slope may, from something being out of order, necessarily be heated from the other direction. Difficulties also occur in small pipes where the extra labor and expense required to provide special drains for overcoming this difficulty would not be warranted, particularly as another solution of the difficulty is available, even with pipes of considerable size.

If a blow-off opening be provided at one end of a main to be filled with steam, even if such blow-off be at the higher end, and the steam be admitted at the lower end, any water in the main can be driven out of the blow pipe, provided the steam valve be opened sufficiently wide to keep the pressure continuously maintained against the water. The explanation of this is that if the steam supply be limited, the water will run back under portions of the steam, forming bubbles which may suddenly collapse and produce water rams; but if the steam supply be practically unlimited, or at least sufficient, the steam will force the column of water back along the bottom of the pipe, as any vacuum formed will be filled by the

steam driving back the water. There will be a series of small explosions, which will scarcely be heard, and do no harm, and the seething wall of water will be continually forced forward and finally out of the pipe.

Note the distinction in the two methods of operation necessary to suit the conditions. When the steam is on top of the water, it may be turned on as slowly as desired, and it is better to turn it on slowly, as thereby the heavy castings are heated slowly and are not so liable to be strained; but when steam *must* be turned into the lower end of a descending pipe, which *may* be filled with water, the valve must be opened sufficiently to establish a definite current and keep up the pressure. This will not require the valve to be wide open, but the result will be substantially as though it were so open. Practical engineers, who on sea and land have had to do with turning steam on in pipes, naturally recoil from turning steam on quickly in any pipe, and it is very hard to explain to them the difference. The writer has had to take a party of men of this kind, state the reasons for action, and in one case recollects using as an illustration, that if a farmer with a pitchfork could get an officer on the run, the latter could not draw his sword, turn, and defend himself, as he would be run through before he came to close quarters. The principle applies to the water in an ascending pipe. The column of water once started, the steam, if the supply be made sufficient, follows it up so closely, and in such volume, that no condensation can take place sufficiently to stop the onward movement. The clearing of a pipe in this way requires nerve and judgment, but in one case considerable cold water was driven uphill out of a six-inch pipe, 1,400 feet long, with a difference of elevation at the two ends of fully twenty feet, by letting steam in at the lower end and blowing the water out on the surface of the street through a two-inch blow-off pipe. The blow-off pipes are made no larger than this, even for mains fifteen and sixteen inches in diameter, but it is not considered safe to attempt to clear an ascending main of this size with this size of blow-off pipe. All these mains are more nearly level, have blow-offs at low points, near the valves, and can be blown off by putting steam in, at or near the summit. In heating up an eleven-inch pipe, only 400 or 500 feet long from the bottom, the writer has had the flange taken off the extreme end, in order to give the water free exit and prevent the possibility of a ram.

The greatest drawback, in a commercial sense, affecting all systems for supplying a fluid under pressure to underground pipes, is leakage, with its direct loss of fluid, together with the expenses of inspection and repairs necessary in finding and stopping the leaks. Many gas companies in small cities and villages lose one-third the quantity of gas generated by leakage. This proportion is generally reduced as the quantity sold is increased, but even old established companies in large cities lose ten per cent. in this way. Large quantities of water are also wasted in the extended distribution of towns and cities.

The work of the New York Steam Company was particularly well done, with the intention of reducing this loss to a minimum; still, to the surprise of all, the loss from this cause far exceeds that due to condensation. Of necessity, there are thousands of joints and many hundreds of valves with packed valve stems to the mile. If most of the valve stems and an occasional joint leaked but a trifle each, the loss in the aggregate would be comparatively large.

It is to be regretted that time has not permitted a more complete description of apparatus necessary in carrying out the principles involved in the transmission of steam, and of the particular details of the work of the New York Steam Company. Nearly every one of the branches of the subject discussed could of itself be made the subject of a special lecture, full of detail, possessing more or less interest to those who might be called upon to engage in work of this class.

In closing the engineering view of the subject, it may be stated that all the problems are worked out, and that all details are mechanically successful; and, moreover, the returns on the very large investment of the New York Steam Company are sufficient to invite the attention of capital to new ventures of the same kind.

There is a field for another lecture in a popular view of the questions relating to the uses to which steam from the streets can be put, and the advantages of this method of supply. At this time, but a word can be given to this branch of the subject. It will be understood that steam engines of all kinds and sizes in any location from cellar to garret, can be operated to drive shops, furnish electric light, pump water, and the like, and that heating,

either by live or exhaust steam, can be done on any scale, but it is also true that nearly all the *cooking* of a family can be done by steam. Nothing is lacking, in fact, but sufficient temperature to brown bread and put the finishing touch, as it may be called, upon broiled meats. Meats may be cooked perfectly with steam heat, but they cannot, in the open air, be so highly heated as to give the particular aroma which pleases the taste. Meat of all kinds can be roasted in an oven jacketed with steam more perfectly than in one heated directly by fire, as the juices of the meat are kept in, and, becoming heated, aid in cooking the entire mass evenly and thoroughly. Many large restaurants do all their roasting in steam ovens. Boiling of all kinds is very simply performed in jacketed kettles. An attaché of the New York Steam Company has recently made an invention whereby, by planing the top of a steam table and the bottoms of the vessels to be heated, and using simple clamps, stews can be made and water boiled in vessels not jacketed with steam; the heat being transmitted from below, and the rapidity of heating or violence of the ebullition controlled simply by tightening or loosening the clamps. With steam stoves fitted with these various devices, and having in connection therewith small gas stoves for finishing the broiling of meat, and perhaps gas attachments to the ovens to brown the bread and cake, housekeepers will be provided with a great boon. With the exceptions named, which do not form a large portion of the work, every operation can be performed by simply regulating a steam valve. By these means the objectionable features of handling coal and ashes will be entirely removed, and provision for doing most of the cooking, as well as complete facilities for heating water, and in winter for warming the building, be provided "on tap," so to speak, the same as gas and water.

Thus the sun's energy of ages past, stored in luxuriant vegetation and buried with it beneath débris due to cosmic changes, may now be redeemed from the bowels of the earth as coal, transmitted to a distance as steam, and bring sunlight to the household by lightening domestic labor. Power, heat and even actual light may be obtained and manufactures promoted in most inaccessible and contracted places; and one more subject is now available for the exercise of the talents of the engineers of the future, in their efforts to advance still further the comforts and civilization of mankind.

PIG IRON: INCLUDING THE RELATION BETWEEN ITS PHYSICAL PROPERTIES AND ITS CHEMICAL CONSTITUENTS.

By Alex. E. Outerbridge, Jr.

[*Abstract of a Lecture delivered before the* Franklin Institute, *February 6, 1888.*]

After a few introductory remarks, the lecturer said that the subject is an interesting one, not only to the producer of pig iron, but also to the practical founder, the architect and engineer, the machinist and mechanic, and in fact to everyone who has to do with iron or steel in any way; he was glad therefore, to see so large a proportion of young men in the audience, who had come, no doubt, from the various workshops of this great manufacturing city, and hoped that he would be able to impart to them some new facts which might prove valuable in their daily toil.

Continuing, the lecturer said, that although his subject was a "cast iron" one, it was not devoid of literary and even of romantic features, which, time would not permit him to dwell upon at any length. He then spoke substantially as follows:

It is proper, however, to indicate that the subject has a history of great antiquity and interest, and to point out very briefly this path which you may explore more fully at your leisure, and I would commend to your careful study the admirable "History of Iron in All Ages," by Mr. James M. Swank, the Secretary of the American Iron and Steel Association.

The earliest records of iron are to be found in the books of the Old Testament, which make frequent allusions both to iron and steel. In the fourth chapter of Genesis, Tubal Cain is spoken of as "an instructor of every artificer in brass and iron," and the Biblical Chronology places this expert in the seventh generation from Adam. When David was about to build the temple (nearly 1,000 B. C.) "he prepared iron in abundance for the nails for the doors of the gates and for the joinings." An "iron pen" is mentioned in the nineteenth chapter of Job, which was used to engrave upon rocks, and in the next chapter a "bow of steel" is spoken of.

Iron was a familiar metal to the Egyptians, Chaldeans, Babylonians, Assyrians, and other ancient peoples; it is frequently mentioned by classical authors, among whom are Homer, Aristotle and Pliny. Homer speaks of iron discs being given as prizes to the contestants in athletic games, and also of the method of tempering steel by plunging the hissing axe into cold water. Pliny knew of the magnetic qualities of iron, and alludes to the inexhaustible deposits of ore in the island of Elba and in Spain. These mines are still worked, and thousands of tons are annually shipped from them. India has been celebrated for ages for the quality of its steel, and China also claims great antiquity for the process of making iron and steel; the Chinese record minutely describing these methods is still preserved, to which almost fabulous age is accredited by archæologists.

These brief allusions must suffice to indicate the rich store of knowledge upon this branch of our subject, which is available to those who have the time and inclination to pursue it to its fountain head.

It has often been asked, in view of the frequent allusions to the use of iron and steel in ancient times, "why are iron relics of antiquity far more rare than those of gold, silver or bronze?" If you reflect for a moment, the true explanation will be apparent; it is owing to the oxidizable character of the metal, which causes it to rust and crumble away, when exposed to the elements, in a comparatively brief period of time. However, the British Museum is fortunate to have secured, through the labors of Sir Henry Layard, during his explorations at Nineveh, a magnificent and most valuable collection of ancient Assyrian iron armor, shields, battle axes, saws and other objects, which ante-date the Christian era almost 1,000 years. Other specimens were so completely oxidized that although retaining their shape when discovered in the ground, they crumbled to powder on being touched.

Iron is a very widely distributed metal, and is found combined with almost all known elements. Minerals are called iron ores when they contain a sufficient proportion of the metal to pay for its extraction; the ore receives its name either from the locality in which it is found, from its chemical composition, or from its general appearance. Thus we have "bog ore," "magnetic ore," "iron mountain ore," "red and black hematite," "spar ore," etc.

The ancient methods of reducing the metal were exceedingly simple and correspondingly crude. A cylindrical cavity was excavated in the side of a hill and the ore and fuel (charcoal) packed into it, a hole being left at the top and bottom for the draught. When the fuel was all consumed, the metallic iron was recovered amid the ashes. The *reguus* was an impure mass, sometimes resembling wrought iron, sometimes cast iron, sometimes steel, and often a mixture of all three, according as the crude process accidentally altered the proportion of carbon, silicon, etc., in the mass.

The next improvement was in the "Catalan Forge," so named from Catalonia, where it originated. The forge was provided with an artificial draught of air from a rude bellows made of goat skins. Then came the invention of the earliest form of blast furnace, which was a decided improvement, owing mainly to the fact that the process of feeding the ore and fuel and reduction of the iron could be made continuous, thus effecting a considerable saving of labor and also increasing the output of metal. The blast furnace is a very simple affair, consisting of a high stack, lined with refractory clay or fire-brick, oval in shape, having one or more orifices near the bottom, called *tuyeres*, for the admission of air under pressure, and an opening at the top, called the "tunnel head," for the admission of ore, fuel and flux. The fuel formerly used was charcoal, and the quality of the metal (called "pig" iron, from the shape into which it is cast as it runs from the furnace) was fa superior, for certain special uses, to that made by modern processes.

I do not mean to say that I think this is necessarily so, or that it will always be true, but I am compelled to admit that, at this stage of evolution in the iron industry, modern improvements have all been in the line of increased output from a furnace with decreased consumption of fuel, but at the expense of the character of the metal and consequent depreciation of value.

In the old-fashioned charcoal furnace air was blown into it at the ordinary temperature. Furnaces of this character were commonly found fifty years ago throughout Pennsylvania, Ohio and all through the South. We are informed by Mr. Swank that such a furnace, producing four tons of iron a day, or twenty-eight tons a week, was considered to be doing well. We now regard an output of 100 tons a day from one furnace, or even 1,000 tons a

week, as quite an ordinary matter. This extraordinary increase has been accomplished, not by a proportionate enlargement of the furnace, but by lessening the time of reduction of the metal and thus increasing its capacity.

It occurred to some one more than half a century ago, that the waste heat escaping from the furnace might be utilized to warm the air blast before entering the furnace, and thus save a part of the fuel. The air was accordingly passed through iron tubes, arranged in a chamber of fire-brick, and thus heated. A very moderate degree of warmth (say 300° F.) imparted to the air, produced a remarkable effect both in saving the charcoal and in hastening the operation of melting. The iron produced by this method is called "warm-blast charcoal iron," to distinguish it from "cold-blast charcoal iron." Furnaces of this class are extensively used to-day along the Ohio River, in the Hanging Rock region and elsewhere. Improved hot-blast stoves were soon devised, whereby a much higher temperature could be imparted to the air, accompanied by increased efficiency and economy of time, fuel and money.

About 1840, a revolution in the manufacture of pig iron in this country was created by the successful introduction of anthracite coal as fuel in place of charcoal in the blast furnace, although some experiments with anthracite had been made at an earlier date. I recently found upon the shelves of the FRANKLIN INSTITUTE library a printed report, published in 1842, of a commission sent from England to investigate this matter, which stated that iron could never be made with anthracite fuel, and deriding the whole scheme. It was quite a surprise to find such an amusing volume among these dusty archives.

Of late years, coke made from bituminous coal has been extensively used as fuel in the manufacture of mill iron, and the product is called "coke iron," to distinguish it from "anthracite iron."

What is the character of the metal produced by these different processes?

Pig iron varies so greatly in general appearance, color, hardness, ductility, tensile and transverse strength and specific gravity, that one not having expert knowledge upon the subject, might reasonably doubt that the specimens which I propose to exhibit to

you, by means of the megascope, even belong to the same class of metal. One specimen is soft and ductile like lead, and shows a rich, dark color and coarse granular fracture; another is hard as steel, brittle as glass, and white as silver, while between these extremes we have a great range of specimens having intermediate qualities.

You now see upon the screen a photograph taken from a series of "test pieces," (see illustrations, *Figs. 1 and 2*) made from different grades of pig iron, in moulds of uniform size, cast in "green sand," against an iron "chill plate" for the purpose of suddenly cooling one side of the casting. The pieces are arranged in a series with the chilled side uppermost, beginning with a sample which shows no tendency to produce white or chilled metal, and passing, by gradual steps, to metal which crystallizes as white iron through the whole mass. All of these specimens were cast from iron which was perfectly gray in the pig, sufficiently soft to bore readily, varying but slightly in specific gravity, and ranging in transverse strength from 5,000 to 7,000 pounds per square inch. The effect of sudden cooling has developed the white crystalline structure in some of the specimens, rendering them so hard that they cannot be touched with a file, and so brittle that they may be readily broken, and increasing their density to such a degree, that a cubic foot of the white metal weighs nearly sixty pounds more than an equal bulk of the gray iron.

Very little information has been printed in regard to the wide differences in the character of *white iron*, although it is a subject of great practical importance to the manufacturer of chilled castings, and it will, no doubt, surprise many to learn that I have found, as the result of a series of careful experiments (not yet published), that there is as wide a difference in the strength of different specimens of white iron as in those of gray iron. Moreover, there is a vast difference in the ability of white iron to resist disintegration or "spalling" under the repeated impact of hammer blows, dependent upon the molecular structure of the crystals. There is also a decided difference in the density, or specific gravity, and hardness of different specimens of chilled or white iron.

I will now show you a photograph (see illustration, *Fig. 3*) taken from a series of chilled iron test pieces, which were cast in iron ingot moulds made for these original experiments, in which you may observe several interesting features. The samples were all

cast from gray iron, some of which showed no tendency to produce white iron when cast in the ordinary "chill moulds," yet in these small ingot moulds they are chilled throughout the mass. You will observe quite a difference in the molecular arrangement and size of the crystals, and what is still more singular, you will see in all of the square sections a plainly marked cross, or dividing lines, extending from corner to corner of the ingot. White iron always crystallizes in planes at right angles to the chilling surface, and, as the moulds are made of iron, the crystals start from all four sides at the same instant, and meet at points equi-distant from the surface, which may be called the neutral line. By splitting some of the ingots lengthwise, I have found this line extending, plainly marked, through its entire length. It is an interesting phenomenon that the line of demarcation of opposing crystalline forces should be so clearly defined. It will be noticed in the specimens cast in the cylindrical moulds, that the crystals radiate from the centre like the spokes of a cart wheel. Some of the specimens here shown are so brittle that the slightest tap from a light hammer will break them, while others of the same diameter require more than 100 blows to break. Some of them are much harder than others, while the difference in density amounts to nearly ten pounds to the cubic foot, as ascertained by specific gravity determinations. These experiments are novel and interesting from a scientific standpoint, while they also have a practical bearing upon the manufacture of good chilled castings.

Of what is pig iron composed that it should develop such widely varying characteristics? Is the iron itself inherently different in quality, or are these changes due to variations in the proportion of the other elements combined with it? You might suppose that you could obtain answers to these questions from practical melters or superintendents of foundries, but you will find even in the largest foundries lamentable ignorance on such points. As an extremely absurd instance, I may mention that some time ago I visited a large iron foundry, and while conversing with the foreman of the melting department, I asked his opinion of a certain brand of iron with which I was familiar. He replied: "Me and my boss wouldn't have a pig of it on the premises." On being pressed for the reason of his prejudice, he replied: "Well, sir, my opinion is, *it's got too much ammonia in it!*"

The chemistry of iron, in its connection with the manufacture of Bessemer steel, has, from the necessities of the case, been carried to a fine degree of perfection, but it is a matter of surprise that so little is known practically in the foundry and workshop, in regard to the cause of these wide variations, which are a frequent source of difficulty in manipulation of the metal, and loss of time, money and labor. The subject is, however, beginning to attract a share of the scientific attention which has been bestowed upon the chemistry of steel, and upon which the success of that industry so largely depends.

In 1885, Dr. Percy, the eminent English metallurgist, in an address before a distinguished body of scientists, said: "It is not many years since we had to grope about to discover an analysis of pig iron, whereas now we are actually overwhelmed with such analyses. What is now wanted is the man to reduce it to law and order—to evolve from it principles for our sure guidance."

Prof. Turner, of Mason College, Birmingham, Eng., speaking on the same subject more recently, said: "All who are acquainted with the various branches of iron analysis must feel how true the foregoing remarks are in the present state of our knowledge. * * Our knowledge cannot be considered complete until we are able to correctly estimate the mechanical value of any given specimen of which the chemical analysis is known; and conversely, when any given mechanical properties are desired, we should be able to say at once what would be the most suitable composition for the material."

Having quoted the remarks of these distinguished authorities, it may not be inappropriate to read a sentence from a brief paper of my own, ante-dating the above, published in the *Penn Monthly* in February, 1882, bearing upon this subject: "Manufacturers are beginning to realize that pig iron is not a simple substance, but is in reality an alloy, composed of a number of dissimilar elements; that its physical characteristics, such as strength, elasticity, etc., depend upon the percentages of these constituents, and that pure iron, like pure gold, is always the same thing physically and chemically, no matter from what source it may be obtained. We believe that the time is coming when pig iron will be sold on its chemical analysis, instead of on the crude methods of grading at present in vogue, and farther, that, as the naturalist can accu-

rately tell the *genus* of an animal from an examination of a single bone, so the analyst will tell the physical qualities of a mass of iron from an analysis of its component parts."

The great differences observed in physical characteristics of pig iron are due, not to variation of the proportion of iron in the pig (which remains constant within a few points), but to the varying percentages of the other component elements, viz., carbon, silicon, sulphur, manganese and phosphorus, and experience has proved that a change of less than one-half of one per cent. of one of these elements (silicon) is sufficient to make or mar the daily product of at least one important iron industry, viz., the manufacture of chilled cast-iron car wheels.

We will briefly consider the effect upon pig iron of these foreign elements in the order of their relative importance.

The element which exerts the most vital influence upon the character of pig iron is carbon. This is strikingly shown by Mr. Fairbairn, who says:

"The metal in the form of cast iron, containing four per cent. of carbon, has a tensile strength of 18,000 pounds to the square inch, and is worth £3 per ton. Deprive it of this four per cent. of carbon and it becomes malleable iron, with a tensile strength of 56,000 pounds, and is raised in value to £8 per ton. But leave in it one per cent. of the carbon it originally contained, and it will have a tensile strength of at least 130,000 pounds, and its selling price rises to £50 per ton." This price, of course, refers to crucible steel at the time he wrote.

Carbon exists in pig iron in two distinct forms, and upon the relative proportion of each depends, in great measure, the character of the metal. It is present either in the form of graphite or free carbon, disseminated throughout the mass in black shining particles, in which case the iron is exceedingly soft and ductile, or it is in part or wholly combined chemically with the iron, causing the metal, when cooled suddenly, to crystallize in parallel planes, presenting a perfectly white fracture, and the metal becomes harder than steel and extremely brittle; advantage is taken of this peculiar quality in the production of chilled castings, as in cast-iron car wheels, ploughshares, etc.

Cold blast charcoal iron contains a larger proportion of combined carbon than warm blast charcoal, anthracite, or coke iron, hence its peculiar value for chilled work.

Pig iron contains from two and one-half to four per cent. of carbon.

Silicon stands next in importance to carbon, in respect to its effect upon the character of the metal. It exerts a controlling influence upon the chilling properties of the iron, since its tendency is to prevent the chemical combination of the carbon and iron. A very small variation in the percentage of silicon produces a prodigious effect in this particular. In a paper read before the Chemical Section of this INSTITUTE, in 1883, upon the "Genesis of a Car Wheel," I explained at some length the important bearing which silicon has upon that industry; a brief extract will suffice to indicate its scope: "The most important difference between a car wheel and any ordinary casting is the fact that the 'tread' of the wheel, viz., that part which runs upon the rail, is quite different in character from the 'plate' or main body, though cast from the same metal in one pouring. The tread, or rim, is actually harder than steel, thus enabling it to resist not only the wear upon the steel rail, but the still more destructive grip of the brakes, and its average 'life' is not far from 100,000 miles of service. The process by which the hardening of the tread is produced is called 'chilling' (see illustration, *Fig. 4*), * * * but it must not be supposed that all irons possess this property, for it is a comparatively rare one, and little is known, even among expert iron masters, of the causes which produce it. Very recently some light has been thrown upon the subject by the aid of chemical analysis, and scientific investigation will doubtless reveal still more clearly what is as yet but dimly seen. * * * It has been found, for example, that the substance, silicon, which is always present in pig iron, exerts an extraordinary influence upon its chilling power, and a variation of less than one per cent. of silicon is sufficient to make or mar a car wheel; indeed, it has happened that an entire day's work of several hundred men has been spoiled by an excess of one-half of one per cent. of this substance creeping undetected into the mixture."

The notion has long prevailed (like many other fallacies born of ignorance) that silicon produces "blow-holes" or unsound castings, but such is not the case; on the contrary, its tendency is to produce an exceedingly fluid iron, retaining its heat for a long time, owing, I believe, to the fact, not generally known, that the

"specific heat" of iron, rich in silicon, is much higher than a similar grade of metal containing but little of that element. Unfortunately we cannot measure the temperature of molten iron accurately, but I am convinced that pig iron varies in its melting point just as it varies in chemical composition, and that this variation extends through a range of many hundred degrees. It is a modern practice, especially in England, to substitute a small quantity of "silicon pig" in the cupola for the more expensive Scotch irons, in order to obtain soft castings from a mixture of pig iron and scrap. The proportion of silicon in pig iron may vary from three-tenths of one per cent. to three and one-half per cent.

Phosphorus as an element in pig iron tends to render the molten metal very limpid, so that it will take an extremely fine and sharp casting from the most delicate patterns. The famous Berlin castings of reproductions in iron of ancient armor and other ornamental objects, are obtained by using iron rich in phosphorus, but it possesses the disadvantage of rendering the metal brittle and unfit for many practical uses. Through the kindness of Messrs. Thackara & Sons, of this city, I am able to exhibit to you some exquisite examples of Berlin ware, and also a Russian casting representing mounted Cossacks, which is as fine in detail as any bronze casting.

I do not consider it essential to use iron high in phosphorus in order to obtain these artistic effects, and in proof of the assertion I am able now to show you a most creditable experiment made by Messrs. Bureau Brothers, the bronze founders, of this city, for illustration in this lecture, from ordinary foundry iron. The specimen is shown just as it came out of the sand, and it compares favorably in delicacy of detail and fineness of texture with the finished foreign productions, while the design is a meritorious work of art.

The percentage of phosphorus in pig iron may vary from a trace to one and one-half per cent.

Manganese is commonly supposed to exert a hardening tendency upon pig iron, but experience has taught me to regard this as another mistaken notion, it undoubtedly produces a marked effect upon the character of the white crystalline structure. You may readily recognize "a manganese chill" by its coarse lamellar or foliated filaments and by the tendency which it produces to form

white iron or "hard spots" in isolated places throughout the gray portion of a casting. Manganiferous pig iron has been used to produce chilled castings, but it does not make a durable wearing surface; the chilled tread of a car wheel, for example, produced by this method, presents to the eye, when broken through the section, a handsome appearance, but the white metal is comparatively soft; it may be easily bored, and, what is more serious, it crumbles readily under the impact of rapid shocks on the rail.

A remarkable effect is produced upon the character of hard iron by adding to the molten metal, a moment before pouring it into a mould, a very small quantity of powdered ferro-manganese, say one pound of ferro-manganese in 600 pounds of iron, and thoroughly diffusing it through the molten mass by stirring with an iron rod. The result of several hundred carefully conducted experiments which I have made, enables me to say that the transverse strength of the metal is increased from thirty to forty per cent., the shrinkage is decreased from twenty to thirty per cent. and the depth of the chill is decreased about twenty-five per cent., while nearly one-half of the combined carbon is changed into free carbon; the percentage of manganese in the iron is not sensibly increased by this dose, the small proportion of manganese which was added being found in the form of oxide in the scoria. The philosophical explanation of this extraordinary effect is, in my opinion, to be found in the fact that the ferro-manganese acts simply as a deoxidizing agent, the manganese seizing any oxygen which has combined with the iron, forming manganic-oxide, which being lighter than the molten metal, rises to the surface and floats off with the scoria. When a casting which has been artificially softened by this novel treatment is re-melted, the effect of the ferro-manganese disappears and hard iron results as a consequence.*

* A few years ago, Mr. William Wilmington, of Toledo, O., patented a process for softening the hubs and plates of car wheels without affecting the chilled tread by sprinkling powdered ferro-manganese into the head box after the mould is partly filled. It is claimed that new wheels are being made in this manner out of old wheels without the use of pig iron. Mr. Wilmington's patents do not cover the process of softening hard iron in the manner described above.

The percentage of manganese in pig iron may vary from a mere trace to two per cent., or even more.

Sulphur is, without doubt, the most deleterious substance found in pig iron. The other elements all produce effects which may be beneficial for certain purposes, but sulphur is an enemy greatly to be dreaded, since it has a strong affinity for iron, combining with it at a low temperature; it is even possible to bore a hole in red-hot iron by means of a stick of sulphur, yet I have actually seen shrinkage holes and cavities in imperfect castings filled with a composition of melted sulphur, the manufacturer failing to appreciate the deleterious effect which this material will produce upon the iron when the worn-out casting comes back to be re-melted, and this is but one of many blunders which are committed through ignorance on the part of practical founders.

The presence of sulphur in pig iron is due mainly to bad fuel or to imperfect roasting of the ores containing that element, or to improper fluxing. The proportion of sulphur in pig iron may vary from a mere trace to more than one-half of one per cent.

These various elements all produce sufficiently marked effects upon the fracture and general appearance of pig iron to enable an expert, who carefully studies the matter in connection with the analysis of the iron, to estimate by the eye the approximate composition of any given sample within a surprisingly close margin of error. In the case of silicon, I have found by frequent tests that it is possible to predict the percentage of that element within three-tenths ($\frac{3}{10}$) of one per cent. of the actual amount subsequently reported by chemical analysis, and although I have not yet succeeded in estimating with equal success the proportion of the other component elements of pig iron, I believe the method by inspection is susceptible of great development.

Traces of other elements are also found in pig iron, but these do not appear to exert a very important influence upon the character of the metal, and cannot be considered in detail at this time.

It is difficult to define the line of demarcation between pig iron, steel, and malleable iron, since one blends almost insensibly into the other. The following table represents fairly well the extreme variations in composition of these three forms of iron

	Pig Iron.	*Steel.*	*Malleable Iron.*
Iron, ...	90 to 95	98·5 to 99·5	99 to 99·5 per cent.
Carbon, . . .	2·5 to 4	1·5 to 0·5	0·1 to 0·5 "
Silicon, . . .	0·2 to 3·5	Tr. to —	0 to Tr. "
Sulphur, . . .	Tr. to 0·5	Tr. to —	0 to Tr. "
Phosphorus, . .	Tr. to 1·5	Tr. to —	0 to Tr. "
Manganese, . .	Tr. to 2·	Tr. to 2	0 to Tr. "

The development of the iron industry in the United States has been truly marvellous. In 1810, we produced less than 54,000 tons of pig iron; in 1840, less than 300,000 tons; 1860, less than 900,000 tons; in 1885, over 4,000,000 tons; in 1887, 6,417,148 tons, made in twenty-three states and territories, of which Pennsylvania alone produced 3,684,618 tons, or a little over one-half of the total amount. It would thus appear that the agitation over the fear that our state is losing its supremacy as a producer of pig iron is refuted by the facts so carefully gathered by Mr. Swank. In addition to this vast production, we imported last year nearly 500,000 tons of foreign pig iron, besides 283,836 tons of "tin plates," or thin rolled iron coated with tin.

Notwithstanding the progress we have made in every other branch of iron industry, we make almost no tinned iron. Why? Ah! thereby hangs a tale, with a moral appended, which may be respectfully referred to the present administration.

It appears that in the tariff act of 1864 Congress passed a law providing that the duty on "tin plates, and iron galvanized or coated with any metal by electric batteries or otherwise," should be two and one-half cents per pound. Now "tin plates," as you all know, does not mean sheet tin, but *sheet iron coated with tin*, and is the material of which all tinware is made. The plain object of this duty was to encourage the establishment of rolling mills for the production of the sheet tinned iron in this country, and, as we had no native tin, it was desirable to place a comparatively low duty upon that metal. Another clause in the same act provided that the duty on "tin in sheets or plates, terne or taggers' tin," should be fifteen per cent. *ad valorem*. Soon after the passage of this law, the Collector of the port at New York applied (as is stated in the Chicago *Inter-Ocean*) to the then Secretary of the Treasury, for a ruling upon the duty on "tin plates." The Secretary replied, under date of July 22, 1864: "It would appear that an error of punctuation has been made by some one, most

probably by the clerk who engrossed that part of the act. If the comma after the word 'plates' be omitted and a comma inserted after the word 'iron' the true sense will be apparent, which unquestionably is that tin plates must be galvanized or coated with some other metal to bring them within this provision." The Secretary then applied the second clause relating to tin in sheets or plates to the case, so that the duty, instead of being two and one-half cents per pound, was assessed at fifteen per cent. *ad valorem*. The immediate result of this ruling was to give an immense impetus to the business in England, more than fifty rolling mills were established for making tin plates for the American market, and ever since that date we have been consuming more than two-thirds of the entire English production of tin plates, for which luxury we have paid more than $250,000,000 to our English cousins.

Let us turn now to a more pleasing chapter in the history of the development of the iron industry, viz., the manufacture of Bessemer steel, which has grown in the past twenty years from an insignificant beginning to one of gigantic proportions. In 1867, the first steel rails were made in this country at a cost to the consumer of $170 a ton. In 1881, we made 1,355,519 tons, at a cost of $61 a ton. In 1886, we made 2,000,000 tons, at a cost of about $30 a ton, and in 1887 our output was still larger.

Having briefly reviewed the early history of iron and the methods of extraction, the character of the metal as determined by its composition, and the enormous development of the industry in recent years, it is fitting that we should consider in conclusion the various uses to which this product is applied.

We are told that the equipment of railways consumes more than one-half of the world's production of iron, and when we consider that we have more miles of railway in the United States than any other country, or, indeed, the whole of Europe, we can begin to appreciate the magnitude of the needs for the raw material; it is estimated that there are more than *ten million car wheels* required to furnish the rolling stock in this country, these alone consuming more than 2,000,000 tons of iron.

In the manufacture of stoves, ranges, cooking utensils, iron pipe, rolled iron, nails and spikes, fire-arms and cutlery, sewing machines, fire-proof safes, steam fire engines, pumps, hammers,

elevators, planers, saws, axes, general hardware, machinery and all kinds of machine tools, we consume vast quantities of iron, and in most of these products we lead the world both for excellence of workmanship and economy of production.

In the field of artistic cast-iron work we have scarcely made an opening. It is in this direction that I think the greatest opportunity for developing the skill and ingenuity of our young mechanics may be found, and for this reason I have taken the pains to secure specimens of the finest foreign work, and also of our home productions, for your inspection.

Our thanks are due to the various manufacturers who have contributed these interesting and beautiful specimens, and on my own part I desire to thank you for the close attention you have accorded to the subject, as well as for the cordial appreciation of my effort which you have shown.

EXPLANATION OF PLATE.

Figs. 1 and 2 show eight "chill test" samples, cast from different specimens of gray iron arranged in a graduated series, ranging from one showing no tendency to crystallize as white iron, to one which chills white throughout the sample.

Fig. 3 shows the remarkable crystalline structure of white iron ingots cast from gray metal in iron moulds, the crystals forming at right angles to the chilling surface, reveal a well-defined line of demarcation at points equidistant from the surface.

Fig. 4 shows a broken section of a chilled cast-iron car wheel, cast in a "green sand" mould, provided with an iron ring, or "chill" producing a chilled or hard iron tread, with a soft gray iron hub, plate and arms.

PAILLARD'S NON-MAGNETIC COMPENSATING BALANCE AND HAIR-SPRING FOR WATCHES.

By Prof. Edwin J. Houston.

Considerable ingenuity has been expended from very early times in the effort to produce a time-piece whose rate is sufficiently accurate for the determination of longitude. It was not, however, until about the middle of the eighteenth century that even approximate success was reached in this direction.

Trifling changes in the rate of movement of the balance-wheel of a watch make a considerable difference during a run of twenty-four hours. Taking five beats per second as the rate of movement existing in most watches, a variation of but the one-thousandth part of a vibration would make a variation of ninety seconds in each day.

The principal causes that tend to produce a variation in the rate of a well-constructed watch are as follows:

(1) Variations of temperature.

(2) Oxidation of the balance-wheel or the hair-spring.

(3) The influence of position on the balance-wheel.

(4) Variations in the force of recoil of the hair-spring.

(5) Variations in the barometric pressure.

(6) Magnetic retardations or accelerations due to the influence of magnetism on the balance-wheel and the hair-spring.

The influence of changes of temperature on the rate of movement of the balance-wheel arises not only from variations in the distance between the point of support and the centre of oscillation of the balance-wheel, but also from variations in the elasticity of the hair-spring consequent on variations in temperature. A compensating balance-wheel, such for example as that first introduced by Harrison, although correctly proportioned to maintain constant the distance between the centre of oscillation and the point of support despite changes of temperature, would nevertheless be unable to rigorously maintain the same rate unless some device is employed to correct the variations in the elasticity of the hair-spring that accompany changes in temperature. Indeed the variation in the rate of the balance-wheel, due to these latter changes, is greater

proportionally than the variation due to changes in the virtual length of the pendulum of which we may regard the radius of the balance-wheel to consist. Berthoud has shown that eighty per cent. of the variations due to differences of temperature arises from the accompanying differences of elasticity in the hair-spring, while the remaining twenty per cent. only is due to expansion or contraction.

Considerable skill has been reached by practical watchmakers in adjusting the various parts of a watch, so as to avoid variations in the rate of the watch from the first four causes already enumerated. No matter how carefully and with what nicety such adjustments are made they are valueless unless the watch can be protected from the influence of magnetism.

In a practical age like the present, it is scarcely necessary to insist on the very great necessity for accurate, reliable time-pieces. Not only to the navigator, but alike to the railroad engineer, conductor, traveller, artisan or professional man, accuracy in time is one of the essentials to success.

The very remarkable growth of electrical appliances that has occurred during the last decade, renders it easy to injure the best watches by inadvertently bringing them into a magnetic field. A necessity therefore exists for protecting watches from the influence of magnetism.

Heretofore such protection was given to watches by placing them within magnetic shields, which, for the greater part, consisted practically of boxes of iron or some other para-magnetic material. Though affording magnetic protection to watches from comparatively weak fields, such devices are for the greater part cumbersome and clumsy, and, unless quite massive, are unable to protect the watch from the effects of powerful fields.

Mr. C. A. Paillard, the well-known adjuster of watches, at Geneva, Switzerland, has devoted considerable time to the production of a watch that shall be free from the various causes for variation in rate, including those of magnetism. After some fourteen years of experimentation he has succeeded in producing a watch that appears to be absolutely free not only from changes in temperature, but also from the disturbances of magnetism. Indeed Mr. Paillard's watches, from the character of their

construction, appear to be more correctly compensated for variations in the actual length of the radius of the balance-wheel, and for variations in the elasticity of the hair-spring, due to changes in temperature, than the watches that have no magnetic protecting devices; or, in other words, the details of construction introduced into the watch by Mr. Paillard to free it from the influence of magnetism, at the same time make it less liable to be affected by changes of temperature than the watches heretofore produced.

Believing that the effects of magnetism on the rate of a watch were practically limited to the balance-wheel and the hair-spring, Mr. Paillard, by constructing these parts of non-magnetizable materials, has produced a watch that appears to be practically uninfluenced by even the most powerful magnetic fields.

A material suitable for replacing the steel in the compound balance-wheel, or in the hair-spring of a watch, must, it is evident, possess the following properties:

(1) It must be unoxidizable in moist air.

(2) It must be permanently elastic.

(3) It must possess approximately the same elasticity at comparatively wide ranges of temperatures.

(4) It must be non-magnetizable.

After extended and laborious research Mr. Paillard has produced various alloys of palladium possessing the above properties. These alloys are used for the hair-spring, and for the compensating balance-wheel. The screws placed in the rim of the compensating balance-wheel for weights are made of gold and of platinum. Besides these parts there is a non-magnetic escapement, that is the escape-wheel, pallets, lever, fork and double roller-tables which are made of some non-magnetic substance, generally of a non-magnetic manganese bronze, while in the finer watches an alloy of palladium capable of being hardened is sometimes used.

The train (or wheels) is made of brass, and the pinions, screws, stem-winding mechanism and main-spring, as well as the springs of the hunting-case are made of steel.

Mr. Paillard has patented his inventions in this country as well as abroad. His United States letters-patent are four in number, and are as follows, viz., Nos. 367,158, 367,159, 367,160, and 367,161. These are all dated July 26, 1887, and are entitled patents for alloys.

The subject-matter of the invention described and claimed in No. 367,158, is thus stated in the specification; viz.:

"In spiral or hair-springs for watches and other time-pieces it is very desirable to substitute for steel, of which they are usually composed, a substance that is neither oxidizable nor magnetic, but which shall possess some of the properties of steel; that is to say, small capabilities of dilatation, hardness, and elasticity."

The meaning here is evidently, that the alloy shall possess hardness and elasticity, and small capability of dilatation.

"My invention relates to a metallic alloy and is composed of the metals hereinafter mentioned, or their equivalents, and is useful in the mechanic arts, and especially in the manufacture of balances, hair-springs, and the other parts of watch, clock, or chronometer mechanisms."

"One object of my invention is to produce an alloy which shall be unoxidizable and non-magnetic."

"A further object of my invention is to produce an alloy which shall possess some of the characteristics and properties of iron and steel—viz., hardness, elasticity, and ductility—and, at the same time be substantially, if not absolutely, non-dilatable."

The inventor points out very clearly the necessity that exists for the balances and springs, particularly the hair-springs of watches, to be constructed of materials that are unaffected by rust or oxidation, by ordinary temperatures, or by magnetic or electrical influences. He ascribes previous failures to produce such springs not only to faulty construction, but especially to the fact that no alloys possessing the necessary properties had been discovered. He then points out the great increase in electrical contrivances, and the consequent greater liability of time-pieces to disturbances in the regularity and uniformity of the action of the springs and balance-wheels.

"All of the difficulties mentioned, as well as those experienced by changes of climate, season, locality, whether on land or sea, or either, of altitudes, the descent into mines of whatever character or depth, or from any cause or influence other than mechanical displacement or destruction, are practically, if not entirely overcome by springs or balances properly made of the alloy invented and manufactured by me."

The alloy described in this specification contains the following metals, viz.:

Palladium,	60 to 75 parts.
Copper,	15 " 25 "
Iron,	1 " 5 "

We will for convenience call this alloy No. 1.

The specification states that the preceding proportions or percentage may be somewhat varied, without appreciably affecting the essential characteristics or properties of the alloy.

The process for the production of this alloy is as follows: About half of the palladium to be used is placed with the other metallic ingredients and with a small quantity of borax and powdered charcoal in a clay crucible and heated until melted. The remaining part of the palladium is then added, and when the whole is melted the molten mass is poured into a suitable mould and when cooled is ready for use.

U. S. Pat. No. 367,159, describes an alloy cheaper in its production and suitable for a lower grade of watches, or for certain parts of watches.

The inventor makes the following statement in the specification: "I have found by experiment that the alloy hereinafter described and claimed can be successfully employed in the manufacture of watches and time-pieces for all the parts not required to be non-magnetic and hardly dilatable, as it is not perceptibly affected by ordinary magnetic or other disturbing causes or influences. The cost of its production is also such that it can be profitably and economically used for all the ordinary parts of watches and for the mechanism of the cheaper grade of watches, where perfect uniformity and regularity of movement under all circumstances is not required."

The composition of the above alloy (No. 2) is as follows:

Palladium,	50 to 75 parts.
Copper,	20 " 30 "
Iron,	5 " 20 "

The method adopted for its manufacture is the same as that described for the first alloy.

U. S. Patent, No. 367,160, describes an alloy possessing in the highest degree the properties desired in parts of high-grade watches liable to change of rate.

The inventor makes the following statement in the specification of the above patent: "The alloy which forms the subject of this application I have found by experiment to be non-magnetic, unoxidizable, hardly dilatable, ductile and elastic in the highest degree; in fact, to be capable of withstanding the severest tests without change or impairment.

"In the manufacture of watches, chronometers and other timepieces, where perfect time and the greatest uniformity and regularity of action are required, the balance and springs must be made of such material that they will not and cannot be affected by natural and artificial causes and forces which do not amount to displacement or destruction of the parts."

The following is the composition of the alloy (No. 3) that is described and claimed in this patent:

Palladium,	65	to	75	parts.
Copper,	15	"	25	"
Nickel,	1	"	5	"
Gold,	1	"	2½	"
Platinum,	½	"	2	"
Silver,	3	"	10	"
Steel,	1	"	5	"

The same method is used in the manufacture of this alloy as in the preceding alloys.

U. S. Patent, No. 367,161, describes an alloy which besides possessing the properties of the preceding, possesses the additional property of being raised by tempering to a very high degree of hardness. He uses the alloy as follows: "In order that the best result may be obtained in watches and chronometers, I have found that it is necessary that other parts of the mechanism employed therein, viz., the escape-wheel, escape-lever, guard-pin, and regulator-index shall possess the same characteristics and properties, and in addition thereto be capable of being tempered to a high degree of hardness to prevent wear and abrasion."

The parts above mentioned are the parts which, as we have seen, are sometimes made of manganese alloy.

This alloy (No. 4) has the following composition, viz.:

Palladium,	45	to	50	parts.
Silver,	20	"	25	"
Copper,	15	"	25	"
Gold,	2	"	5	"
Platinum,	2	"	5	"
Nickel,	2	"	5	"
Steel,	2	"	5	"

The process of manufacture of this alloy is the same as that used in the other alloys.

Fig. 1 shows a compensating balance-wheel. It consists as shown of two arms or segments. These segments consist each of

FIG. 1.

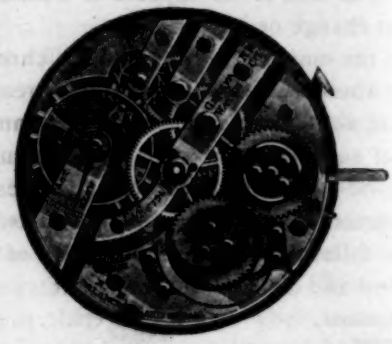


FIG. 2.

two laminæ of different palladium alloys, the coëfficients of expansion of which are so proportioned as to permit them to act as in the compound balance-wheels of brass and steel, to obviate the effects of changes of temperature by preserving constant the dis-

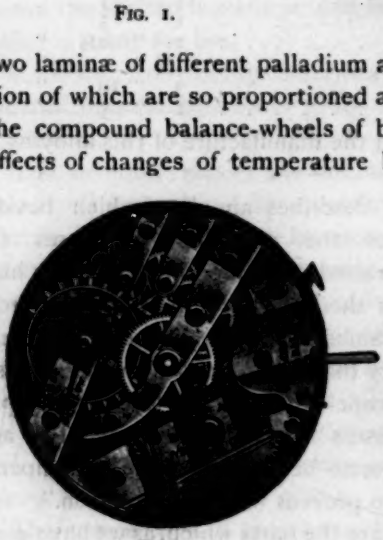


FIG. 3.

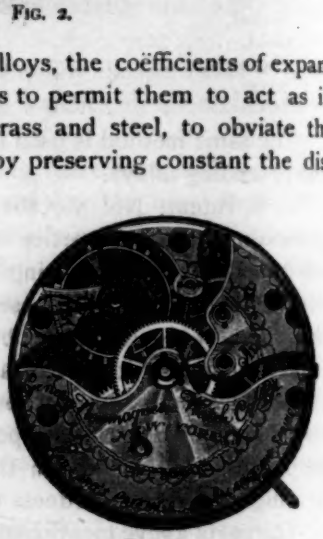


FIG. 4.

tance between the point of support of the balance-wheel and its centre of oscillation.

Figs. 2, 3 and *4*, show different movements. *Figs. 2* and *3* are bridge movements, *Fig. 4* is a ¾ plate movement.

Two watches were employed in the experiment about to be described, which I will designate as No. 1 and No. 2.

No. 1, had the Paillard palladium alloys in the balance-wheel and in the hair-spring, and had in addition a non-magnetic escapement. Experiments were made with this watch, both without and with a hunting-case.

No. 2, had the Paillard palladium alloys in the balance-wheel and hair-spring. The escapement was of steel.

The author is indebted to Mr. A. C. Smith of the Geneva Non-Magnetic Watch Company, of New York, for the loan of the first of these watches, and to Mr. Geo. W. Banks, of the firm of Bailey, Banks & Biddle, of Philadelphia, for the loan of the second.

The following experiments were made to test the non-magnetic character of the palladium alloys and the extent of the protection afforded to the watches before alluded to, when placed in various magnetic fields.

Two palladium hair-springs of different alloys were placed in a uniform field, the direction of the lines of force in which was determined by a very thin layer of iron filings. On placing the springs in various positions in the field no change in the grouping of the lines was observable. They were neither concentrated on the palladium alloys nor repelled from them; that is to say, they were neither appreciably paramagnetic nor diamagnetic.

According to the experiments of Faraday and the later investigations of Plücker, palladium is a paramagnetic substance; that is to say, it concentrates the lines of force upon it after the manner of iron. Its paramagnetic properties are however comparatively feeble.

Bearing in mind the paramagnetic character of many of the components of the preceding alloys, their failure to exhibit any of the properties ordinarily recognized as magnetic is interesting from a scientific standpoint. Thus in alloys Nos. 1 and 2 the copper is the only component that is diamagnetic. In alloy No. 2, the steel and nickel are powerfully paramagnetic, and the palladium and platinum are also paramagnetic. The copper, gold and silver only are diamagnetic. In alloy No. 4, all the components are paramagnetic except the copper, silver and gold.

The masking of the paramagnetic properties of some of the components of an alloy would seem to point to the probability of such alloys being formed by true atomic, or chemical combination.

In order to observe the effect of an intense field on the springs

they were placed in the very powerful field of an electro-magnet the massive pole-pieces of which were but a few inches apart. No deflection of the light springs was observed when suspended in this field. When allowed to fall through the narrow gap between the pole-pieces, they fell quite freely. The intense field failed to produce any appreciable magnetism in them.

Similar experiments were tried with the compensating balance-wheel with the same result.

The above experiments may be regarded as establishing beyond doubt the fact that the alloys tried were not paramagnetic substances, that is cannot be rendered magnetic like iron and steel. They can, however, hardly be regarded as conclusive in respect to their diamagnetic character, since the specimens experimented on did not permit of exhaustive trials in this direction.

In order to determine the effect on the rate of time-pieces, that might be produced by external magnetism, watches Nos. 1 and 2 were subjected to numerous experiments, by taking them into various fields, bringing them near the poles of dynamos while generating current, or actually placing them on the poles. No appreciable effects on the rate of the watches were observed.

In all cases the watches were carefully rated before and alter the experiments. For the rating of the watches the author is indebted to Messrs. Jas. H. Kelly and Edwin Corry, of Bailey, Banks & Biddle of Philadelphia, who attended to the rating of the watches, comparing them with the time as signalled from the U. S. Naval Observatory at Washington, D. C.

To subject the watch to a more severe trial the armature was removed from a dynamo-electric machine, and its field excited by the current from a second dynamo. Watch No. 1 was then placed in various positions and for varying times in the field, directly between the edges of one side of the curved pole-pieces. No appreciable alteration in its rate was observed.

The experiments thus made as to the efficacy of the Paillard palladium alloys in preventing change of rate in watches due to external magnetism by placing the same between the pole-pieces of a dynamo were, as will be seen, of an unusual, and, indeed, unnecessarily severe character. It would be impossible in the ordinary use of a watch to subject it while on the person to fields as intense in any position which the observer can take outside the

machine itself. One would in point of fact, have to remain for some time in between the pole-pieces of a dynamo in order to give the watch an equally severe test, and this is of course an impossibility. These experiments were made with the intention of magnifying any small effects that might exist, so that their character could be determined.

The fact, that under these extraordinary conditions, the watch neither suffered any very appreciable variation in its rate, nor had its adjustment seriously affected, shows the extent of the protection afforded by the Paillard palladium alloys. The non-magnetic character of the balance-wheel and hair-springs and escapement of such watches, render this protection quite intelligible.

I have not been able to discover any change in the rate of the Paillard watch that can be directly or indirectly ascribed to the effects of magnetism, when the watch is placed in any position in which it can be brought while in actual use. If any changes in rate do in point of fact occur, they are so extremely minute that I have been unable to detect them, since they are completely masked by the changes, that, even in the best-made watch, are liable to occur from the many other conditions that affect its rate.

In order to obtain an actual record of the rate of a watch subjected to powerful magnetic fields, under conditions in which the errors of temperature, position, etc., were removed, it was necessary that the watch should remain as nearly as possible under the same conditions from the beginning to the end of the experiments. Through the courtesy of the general manager, Mr. A. J. De Camp, of the Brush Electric Light Station, at Twentieth and Johnson Streets, Philadelphia, watch No. 2 was taken to this station, and carefully adjusted until its rate was ascertained. The watch during this time was kept in the same position (lying horizontally with its face upwards) in a fire-proof safe. After it was regulated to a fairly close point, it was placed face upwards on the upper pole-piece of a Weston dynamo-electric machine that was producing a current of twenty ampères, under an electro-motive force of 560 volts. It remained in this position for five minutes, when it was again placed in the safe and its rate taken as before.

The following figures give the data of these experiments, viz.:

February 2d, 1888, watch set and placed in safe.
" 3d, " not rated.
" 4th, " 6 seconds fast.
" 5th, " not rated.
" 6th, " 20 seconds fast.
" 7th, " 30 seconds fast, *set* and *regulated*.
" 8th, " 5 seconds fast; *regulated*, but not *set*.
" 9th, " 7 seconds fast.
" 10th, " 9 seconds fast.
" 11th, " 11 seconds fast.
" 12th, " not rated.
" 13th, " 11 seconds fast.

It will be observed that from the 9th to the 11th of February the rate of the watch showed a gain of two seconds a day, and that on the 13th the watch was running with fair regularity.

On the 13th the watch was placed on the pole of the dynamo for five minutes, as before described, with the following results:

February 14th, ... 12 seconds fast.
February 15th, ... 13 " "

There was therefore no sensible effect on the rate of the watch, since this change of one second per day was quite within the possible range of changes attributable to other causes.

It should be borne in mind that the watch experimented on had its escapement of steel and not of the Paillard alloys. This escapement was a straight-line escapement, and its lever, fork, roller-tables, pallet, and escape-wheel were of steel. The favorable showing of the above experiments, in a watch in which these parts were magnetizable, confirms me in the belief, that a watch in which the balance-wheel, hair-spring and the escapement are of the palladium alloys, cannot possibly be affected by any ordinary, or even more than ordinary magnetic field.

Watch No. 2 was now submitted to a more severe test by holding it in the same horizontal position, face upwards, between the opposite pole-pieces of a Brush, sixty-light dynamo, furnishing a current of nine and one-half ampères, and feeding forty-one lamps. The watch instantly stopped. On taking it away from the pole-pieces it was readily started again. This experiment was repeated several times.

The stoppage of the watch was due, I think there can be no doubt, to the fork coming in contact with the steel roller-table.

The field of the machine was of such a character, that my own watch, though some ten times farther from the pole-pieces than the watch experimented on, was stopped so frequently that I was compelled to take my time from a clock on a distant wall.

The watch though placed in a field that stopped it was not affected sensibly in its rate when removed therefrom.

There was thus obtained a practical demonstration of what was to be expected from the non-magnetic character of the balance-wheel and the hair-spring. If these are non-magnetizable the watch should not, apart from considerations hereafter considered, be affected by magnetism.

At the same time the experiment seems to suggest the advisability of making the escapement of all watches of non-magnetizable materials, either of manganese bronze or, preferably, of some of the palladium alloys. Where the deformation of the case or train due to magnetic stress, is to be feared, it would appear advisable to replace the steel springs for the hunting-case by, say manganese bronze. Where such is not to be feared, the steel case-springs probably act as a species of magnetic shield, causing many of the lines of force of an extraneous field to pass through them.

I am satisfied that the stoppage was due to the magnetic character of the escapement, since a watch with the balance, hair-spring and escapement all of non-magnetizable material, when placed in the same field under exactly similar conditions was unaffected.

In order to give some idea of the strength of the magnetic field of the Weston dynamo-electric machine used in the preceding experiment, I would state that a watch provided with what is termed an *anti* (sic) magnetic shield, was instantly stopped when placed under similar conditions. This watch is a very fine one that belongs to a well-known electrical engineer. In order to avoid changes in its rate due to magnetism, he had a gold balance-wheel placed in the watch, but had it subsequently removed since the changes in the rate of the watch due to variations in temperature were greater than those due to magnetism. An ordinary balance was then put in together with the magnetic shield before referred to.

The failure of magnetic shields to protect watches when subjected to the fields it would be exposed to in the neighborhood of powerful dynamos is to be expected, since the small mass of material used would be insufficient to carry all the lines of force through the shield and thus protect the watch.

Since the watches experimented on contain magnetizable materials, such for example as the main-spring, regulator, steel screws, and, in hunting-cases the large case-springs, they must of course acquire a field of their own when taken into a sufficiently powerful external field, and the field they thus acquire they must as a matter of course keep indefinitely. The question therefore arises whether this field must not affect the watch's rate; for, since the balance-wheel and hair-spring are metallic and conductors of electricity, they might, in their to-and-fro movements through the watch's magnetic field, so cut the lines of force, as does the wire on the armature of a dynamo-electric machine, as to effect a retardation of the balance-wheel, and consequently change the rate of the watch.

That such an effect is not produced by the watch's own field to any appreciable extent is shown by the fact that the experiments before recited failed to sensibly affect the rate.

In order to ascertain whether any such effect is in point of fact produced under any circumstances the following experiment was made. The previous experiments having convinced me that so far as the field of the watch was concerned, or even its field when reinforced by comparatively powerful external fields, was unable to produce any measurable results, arrangements were made to obtain an exceedingly powerful field directed so as to produce its maximum effect, and to expose the watch to such a field for a comparatively prolonged time.

Watch No. 1 was exposed to the field of an Excelsior machine from which the armature had been removed and the field excited by the current from a Brush sixty-light arc machine.

In order to concentrate this field on the balance-wheel, massive conical pole-pieces of soft iron tapering to a rather sharp point were attached to the inner pole-pieces of the machine, leaving a space between them just sufficient to introduce the watch, the pole-pieces just touching its face and back respectively. The watch was then placed horizontally, face upwards,

so that the point of the conical pole-pieces came above and below the edge of the balance-wheel nearest the edge of the watch. Under these conditions, the balance-wheel, in its to-and-fro motions, moved alternately into and out of the field, cutting the lines of force at right angles to its motion, and should experience retardation, as in the case of the well-known copper-disc experiment, or, indeed, as already stated, as in the case of an ordinary dynamo-electric machine.

The watch was then left in the field so provided, and in the position stated, for one hour. On its removal from the field it *was found to have gained fifteen seconds.*

A previous experiment made under somewhat similar conditions, in which the field was neither quite so strong, nor so well defined, the conical pole-pieces not being employed, an exposure of forty-five minutes caused a gain of 8¾ seconds.

I had previously expected that the retardation of the balance-wheel would be attended by a retardation of the watch; that is that the watch should lose rather than gain time. Due consideration however will show that the retardation of the balance means a decrease in the arc through which it moves, and this must necessarily be attended by a greater number of oscillations in a given time. In other words the watch, it would appear, must *gain* and not *lose* when moving through the resisting medium of an intense magnetic field.

It is thus shown that a watch in a magnetic field acts like a dynamo-electric machine, and may, under suitable conditions, generate current and experience a change of rate. It might be interesting to inquire whether such temperature changes are produced by such currents as to affect the rate, when the watch is placed under the extraordinary conditions related in the last experiment.

It is a significant fact that, even after the prolonged exposure to the extraordinary field employed in this experiment, no appreciable change in the rate of the watch was observed, although its rate was carefully noted for five days afterwards.

In conclusion, and as a result of all the experiments made, I believe that a watch containing the Paillard non-magnetic compensating balance, hair-springs, and escape-movement can safely be carried into even the most intense magnetic fields without suffering

any appreciable change in its rate; and, that while on the person of its wearer, it cannot possibly be brought into a magnetic field sufficiently strong to alter its rate.

Mr. Paillard has therefore conferred a great boon not only on the electrical engineer but on all those to whom correct reliable time is a necessity.

CENTRAL HIGH SCHOOL,
Philadelphia, February 20, 1888.

BOOK NOTICES.

STEAM BOILER EXPLOSIONS. Thurston, R. H. John Wiley & Sons, New York. 1887. pp. vi–173; 12mo.

This little work, by Prof. Thurston, is a very complete statement of the causes of boiler explosions, and will serve the "excellent purpose of showing that the element of mystery commonly exists only in the imagination of writers * * * and that the causes of accident are wholly preventable and controllable." Being nearly free from formulæ, the information it contains can be readily understood by those having the care of boilers, and should be carefully read by them. The matter advanced has been understood by engineers for some time, but the collection of the facts here given puts the matter in a convenient shape.

The first part of the work is devoted to showing that the energy actually contained in a boiler in use is more than sufficient to produce all the destructive effects usually accompanying explosions. The cause of explosions can always be found to come under one of the following heads: (1) defective design; (2) bad construction; (3) decay; (4) mismanagement. The absurdity of the many theories of the production of gas, electricity, etc., and the necessity of frequent and intelligent supervision are plainly pointed out.

Tables of statistics relating to boiler explosions are given, and also the results of boiler inspections, made by the Hartford Steam Boiler Inspection and Insurance Company. Their inspections show that out of 6,453 boilers in which defects were discovered, 927 were dangerous; and out of 4,409 defective boilers, 457 were dangerously so. A statement of Colburn's theory of the method of explosions and Lawson's experiments to corroborate the theory are dealt with fully.

The bad effects of overheating the iron are shown to be due more probably to the weakening of the iron rather than to the subsequent violent evaporation. The danger of low water and increase of sediment over heating surfaces, is pointed out, as well as the fact that the pressure will rise very rapidly in a boiler in use from which no more steam is taken. Typographical errors make both the formula for determining the time for a given increase of pressure and the application of the corrected formula to the first case incorrect.

Local decay, caused by corrosion, pitting, grooving, etc., shows the necessity of frequent inspection. The advice given under the head of emergencies is excellent, and should be thoroughly understood by those having the actual charge of boilers.

The last part of the book is devoted to instances of explosions, giving their probable cause and destructive effects.

As in Prof. Thurston's other works, throughout this book, where English units are used, their French equivalents are given, but after one becomes accustomed to *not* seeing the quantities in parentheses the annoyance disappears. H. W. S.

RICHTER'S INORGANIC CHEMISTRY. Third American from the fifth German Edition. 12mo. Cloth, $2. P. Blakiston, Son & Co., Philadelphia.

The book before us is the English translation of a well-known German text-book on chemistry. The appreciation of its merits in this country is shown by the fact that the issue of a new American edition has followed rapidly the issue of each of the last three German editions. We have before us the third American edition, translated from the fifth German one. As stated by the translator, the present edition contains a rather extended section upon the thermal behavior of bodies, and throughout the work frequent occasion is taken to call attention to the dynamical side of chemical reactions. The sections upon the pressure and condensation of gases, and that upon the dissociation phenomena, have also been considerably increased, while new facts relating to the elements and their derivatives, to their preparation, etc., have been introduced in their proper places.

The general points of excellence of Richter's book are well known to those (and the number is now quite large) who use it with their classes. They consist in accurate and clear statements of the most generally approved views of chemical theory, a philosophical method of developing the study of the chemical elements and their more important compounds, taking them in natural groups, and constantly calling attention to the group-characters, both the points of resemblance and the gradual differentiation within the limits of the group. This method of treatment has become necessary, if we are to lay any stress upon the "periodic law" theory of Mendelejeff and Lothar Meyer, which makes the properties of the elements and their compounds periodic functions of their atomic weights. The most recent facts with regard to the different chemical elements and compounds mentioned are, in general, well stated. We do not think sufficient prominence is given to the explanation of the "ammonia-soda" process, which, as this edition states, furnishes half of the carbonate of soda made in Europe, and, with the cryolite process, makes all that is made in this country. No mention is made of the manufacture of malleable nickel by the Fleitmann process, which has assumed considerable importance in Germany, nor is any mention made of the newer processes for obtaining metallic aluminium, which have attracted such general attention recently.

We wish, too, that the author, or at least the translator, would drop the use of the terms "nitric oxide" and "nitrous oxide" as applied to NO and N_2O, respectively, as this irregularity only perpetuates the confusion already too great in naming non-metallic oxides.

The book is clearly printed and presents a most attractive appearance.

S. P. S.

MECHANICS OF MATERIALS. Church, I. P. New York: John Wiley & Sons. 1887. 8vo. pp. xvi, and 195 to 514.

This work, which is a continuation of statics and dynamics by the same author, treats of the general laws governing torsion, flexure, tension and compression and their practical application. While there is but little new in the results deduced, the method of treatment is one that makes it excellent as a text-book. After the derivation of the formula governing any particular case, and which is done in the simplest manner possible, there are examples given, such practical ones as engineers are often called upon to solve, and the application of the principle is learned as soon as the principle itself. The graphical method of solution is used freely throughout that part of the book treating of arches, girders, etc., and a sufficient quantity of the principles of graphical statics and graphical arithmetic is given to enable the students to understand their application. The text is freely illustrated, each illustration having on it in its proper place all the data required for its easy understanding. The stress laid upon correct numerical substitution, and the proper use of the units of measurement, together with the examples given, make it one of the most practical books published on the subject, and its freedom from typographical errors makes it an excellent reference book.

H. W. S.

A TEXT-BOOK OF ROOFS AND BRIDGES. By Mansfield Merriman. Pt. 1. Stresses and Simple Trusses. New York: John Wiley & Sons. 1888. 8vo. pp. 118.

All who are acquainted with the works of Prof. Mansfield Merriman, of Lehigh University, will be glad to learn of the publication, by John Wiley & Sons, of a new text-book on roofs and bridges by that author. Perhaps there is not much in the book that is new to those already well versed in the subject, but it is especially adapted to the needs of beginners.

To such, the principles of the science could scarcely be made clearer or stated more concisely, and in this consists the great merit of the author's works.

There are only 118 octavo pages, printed in large type, so that the book may easily be finished in one term of a college course. The volume just published is only Part 1 of a proposed course of four parts, and consists in the treatment of the computation of stresses in roof trusses and in all the common styles of simple bridge trusses; the second part will treat of the analysis of stresses by graphic methods; the third part, of the design of a bridge, including the proportioning of details and preparation of working

drawings; and the fourth part of the discussion of cantilever, suspension, continuous and arched bridges. These, in connection with the author's "Mechanics of Materials," would make an excellent course. Besides the bare mathematical analysis of the stresses, there is much information of a descriptive nature laying stress on the importance of practical knowledge, judgment and skill in the designing of connections, determination of data for the computations, etc., so as to produce a structure of least cost and greatest stability. The author has succeeded in giving a rule, easy of practical application, for finding the maximum stresses due to the wheel loads as actually existing, instead of assuming the loads to be uniformly distributed with a uniform locomotive excess as usually done.

It is to be hoped that the other parts of this course will soon be ready for publication. S. S. E.

GENERAL SPECIFICATIONS FOR HIGHWAY BRIDGES OF IRON AND STEEL. By Prof. J. H. L. Waddell, C.E. Macdonald & Spencer, Kansas City. 8vo. pp. 45.

In this paper the author has started with the most instructive lessons of experience as derived from the failure of highway bridges, reported by Prof. Geo. L. Vose. A short chapter is devoted to the "letting," another to the rule-of-thumb manner of proportioning and assembling, and the next to the means by which these defects may be avoided. The author proposes an association of highway bridge builders to secure better results for all parties to the contract and a greater guarantee as to the safety of the travelling public. The paper closes with a set of very carefully drawn specifications for structures of this class, in which the writer is a recognized authority. It will be found to be a valuable contribution to bridge literature and especially useful to road and county commissioners. H.

TABLES FOR CALCULATING THE CUBIC CONTENTS OF EXCAVATIONS AND EMBANKMENTS. By John R. Hudson. New York. Vol. 2. John Wiley & Sons. 8vo. pp. 82.

The already pretty well overloaded literature on the computation of earthwork volumes is still further augmented by the publication, by John Wiley & Sons, of Volume II of tables by John R. Hudson, M. Am. Soc. C.E. The work contains twenty-three pages of text, and sixty pages of tables. There are also some specimen pages showing form of cross-section sheets adapted to his methods of computation.

The author calls attention to article 9, in which is given a short and simple rule, adapted to "three-level-ground," to take the place of the ordinary method of averaging end areas. The process involves the inspection of tables, and besides this, consists only of addition and subtraction. By comparison of both methods of computing an example he shows a saving of one-third the time required in the common way. This article contains another method of arriving at the same result equally short, as well as a formula giving the prismoidal contents with one-half the labor necessary when the ordinary

form of the prismoidal formula is used. By using his tables of side triangles the computation is much abridged, as the calculation of end areas is dispensed with. Article 8 shows the method of making the prismoidal correction, giving results differing but little from the true prismoidal contents. In article 11 methods for cross-sections for five or more heights are given. There are in all forty-six tables, thirty-six of these being tables of contents for level cross-sections and side triangles for different widths of road bed and side slopes.

It would be a great labor to examine and compare all the methods of abridging earthwork computations that have been published, and determine which one gives the most correct results for the least labor. But we think that Mr. Hudson's tables are well worthy of a careful examination by anyone who has much of this kind of work to do. S. S. E.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

COMPARISON OF WATER GAS WITH ILLUMINATING AND GENERATOR GAS.—Ferdinand Fischer, in *Zeitschrift für die chemische Industrie* (1887), **47**, treats at considerable length of the conditions under which water gas or generator gas seems likely to replace illuminating gas. He considers that metallurgical works, chemical manufactories, and all large establishments of this kind are likely to make free use of water gas, if the cheaper forms of fuel like coke, scrap, etc., are to be had. Water gas is now used at Witkowitz, and will shortly be used at Hörde also, for the Siemens-Martin ovens, the welding ovens, and at Essen for welding axles. It is also adapted for sugar works for burning the lime, and in burning fire-brick and fusing glass for the final high heating. In chemical establishments water gas will find a widespread application; first, as a substitute for ordinary illuminating gas, because it burns with smokeless flame, and readily yields a higher heat; and second, because of the high temperature and the amount of hydrogen, it is adapted to many decompositions, like that of chloride of magnesium. The general introduction of water gas, in the opinion of Fischer, will surely come as soon as it is specially adapted to the different kinds of coal, in which case it will be found desirable first to deprive the coal of volatile matter, as is now done in gas making, and then to work up the fixed carbon into water gas, which, after the collection of the valuable side products, can be mixed with the previously formed illuminating gas. In such a case, as it will not matter whether all volatile matter has been driven out of the coal or not, in the first stage of the process, much lower heat can be used than is now customary in gas works. It is even possible that our present cumbrous methods of gas making will be replaced by others in which coal will be handled exclusively by machinery, first partially deprived of volatile matter, and then at once run into the generator for water-gas making as the second step.

For the supply of a district with illuminating, heating and power gas, only the illuminating and water gas can be considered. In this case, illuminating gas is distinctly less suited, as it contains only twenty per cent. of the heating value of the coal, requires much manual labor in its production, and can only be produced from certain kinds of coal. The water gas process, on the other hand, yields forty per cent. of the combined value of coke and anthracite, as a gas of high calorific value, and by corresponding improvements in the process will likely yield forty-five per cent. This gas can easily be used for illuminating purposes by the aid of a magnesia comb like that of Fahnehjelm (or the von Welsbach net of metallic oxides, and the Sellon-Lewis platino-iridium cage) and for heating purposes is much more convenient, and in most cases much cheaper than coal gas. S. P. S.

"SALUFER" is the name of a new antiseptic, which is being introduced into notice. It is sodium silico-fluoride. The activity of its saturated solution is said to be equal to that of a one-thousandth corrosive sublimate solution. Its freedom from poisonous qualities and its stability will make it a material of great value, if its antiseptic qualities are thoroughly substantiated. A paper, referring to the new antiseptic, by Mr. F. H. Rosengarten, appeared in the December number of the *Amer. Jour. of Pharmacy*. S. P. S.

ON THE DECOMPOSITION OF PETROLEUM NAPHTHA ON HEATING.—It has long been a known fact that in the distillation of Caucasian petroleum, some constituents decompose even at relatively low temperatures. This is shown in the formation of coke deposits in the crude oil stills at Baku, which, therefore, to avoid a burning through, have to be cleaned every seventeen to thirty days. This decomposition of the Caucasian oil did not attract much attention until recently, when Alexejew patented a process for obtaining relatively low boiling products from the crude naphtha by a peculiar process. This consists in distilling in an atmosphere of illuminating gas accompanied by a continuous decomposition of the naphtha. Prof. Lissenko has therefore had Rosenbladt study this process in the laboratory of the Mining School at St. Petersburg, in order to find out the most favorable condition for the decomposition of the naphtha without the use of illuminating gas. The apparatus consisted in a round-bottomed flask of difficultly fusible glass, to the neck of which was fitted a dephlegmator tube, 1·5 cm. wide and 40 cm. in length, from which issued laterally four delivery tubes, set at different heights, 6 cm. apart. In the beginning of the distillation the vapors issued from the top tube, while the three lower ones were closed off. When the vapors cease to issue here, this tube is closed and the next lower one is opened and connected with the condenser and receiver. When this ceases to deliver, the third and eventually the fourth delivery tubes are opened and similarly connected. To determine the temperature at which the distillates were given off, a long glass tube sealed below was lowered through the dephlegmator tube, and in this, glass cylinders containing metallic zinc, bromide of silver, chloride of silver and chloride of lead, were placed. By the fusion of these several substances, the temperatures 400° C., 434° C., 457° C. and 501° C. were determined. The temperature best fitted for the decomposition of the naphtha

was found to be between 434° C. and 457° C. Similar experiments conducted on a larger scale in Nobel's technical laboratory in St. Petersburg, gave 400° C. as the best temperature for this decomposition. Operating in this way with naphtha residues (from which burning-oil fractions had been distilled off) Rosenbladt got sixty-four per cent. of a distillate of sp. gr. 0·805, thirty per cent. of sp. gr. 0·860, and four per cent. of a coke-like residue. The first distillate (sp. gr. 0·805) gave, on fractioning:

Up to 110° C.,	10	per cent.	of a fraction of sp. gr.		0·703
From 110° to 135° C.,	10	"	"	"	0·756
" 135° to 175° C.,	10	"	"	"	0·786
" 175° to 255° C.,	20	"	"	"	0·813
" 225° to 235° C.,	10	"	"	"	0·828
" 235° to 295° C.,	10	"	"	"	0·849
" 295° to 305° C.,	10	"	"	"	0·847
Residue,	20	"	"	"	0·867

The second distillate (sp. gr. 0·860) separated on cooling solid hydrocarbons, while the first mentioned above (sp. gr. 0·805), even after purifying with sulphuric acid and alkali, showed a yellow color and a pyrogenic odor. On separating into fractions by the second distillation, however, it yielded an unexceptionable burning oil, which showed no tendency to become yellow on exposure to the air.

Theoretically, then, Lissenko has solved the problem of decomposing the heavy portions of the crude naphtha into lighter ones, which can be burned as illuminating oil. Practically, the process will not be carried out at Baku, with the present prices of crude oil, as the process involves several distillations and a lengthening of the time necessary for the production of the illuminating oil, so that it is cheaper to take the smaller yield from the crude oil and throw away the residues than to work them up for burning oil.—(*Russian Mining Journal, 1887—349.*) S. P. S.

Report on Tanning Leather, Etc., in Royal Jubilee Exhibition, Manchester. Watson Smith, *Journal Society of Chemical Industry*, **6**, No. 12.—The art of manufacturing sole leather, and some species of upper leather, has been known from ancient times, but it is only during the last half century that tanning has become a science, and that the value of chemistry has been appreciated by the tanner. The manufacture of strap-butts is a growth of the present century, and it has naturally developed with the increased application of machinery throughout the world, until now it may be estimated that there are manufactured from English strap-butts alone upwards of from 35,000,000 to 40,000,000 feet of belting per annum. The manufacture of "clog-butts" is mainly confined to this country (England), and is not an increasing industry. Probably less than 1,000,000 pairs of clogs are made annually in England, and these are made entirely from English leather. The number of hides and skins imported into England for home consumption may be roughly estimated at about 9,000,000 per annum, the bulk of which come from South America, the Cape, Australia, Brazil, Madagascar and the West Indies. With regard to English hides, if we take as a basis the amount of beef consumed in Lancashire, the supply of hides will be about 195,000 to every 500,000 inhabitants. This would mean a total of about 10,000,000 English hides per

annum, and about 1,000,000 calf-skins. The value of these hides (in all about 20,000,000) is probably £15,000,000 to £18,000,000 sterling, and this value, after the cost of tanning, and perhaps currying, has been added, will probably be increased to something between £30,000,000 and £40,000,000 sterling.

The chief tanning agents used in England are oak bark, stripped in English and Belgian forests, valonia from Smyrna, myrabolams from the East Indies, divi divi, Mimosa bark, hemlock and other extracts used in smaller quantities. The staple agents used in currying are cod oil, from Newfoundland, and tallow, melted in England or imported from Russia.

Specimens of heavy and light sole and insole leathers, also army, hydraulic and other machinery leathers were exhibited. The chief characteristic of these materials is their fineness of texture and compactness of pattern, and these qualities are attained by special preparation.

The ordinary sole leather is tanned for nine months in oak bark liquors and three months in strong valonia liquors to give solidity. The leather for army and hydraulic purposes is continued six months longer in the valonia liquors. The "offal" or insoling is tanned for a period of six months only.

The following materials employed in tanning are also shown: *Tanning Extracts.*—Clarified oak, myrabolam, sumac, valonia, larch and divi divi extracts. *Ground Tanning Materials.*—Extra best Palermo sumac, fine ground myrabolams. *Raw Tanning Materials.*—Sumac, divi divi, myrabolams and valonia. H. T.

ESTIMATION OF TANNIN IN EXTRACT OF SUMAC.—T. C. Palmer (*Jour. of Soc. of Dyers and Colourists*, **3**, No. 11).—American manufacturers attempt to purify the extract by removing pectin, which is the supposed cause of the fermentation, or to prevent fermentation by the addition of a germicide. The following is the summary of the author's examination of the unpurified and purified extracts:

THREE SAMPLES EXTRACT SUMAC.

	Ordinary.	*Once Refined.*	*Twice Refined.*
Per cent. of tannin by hide powder after removal of pectin,	26·26	24·70	17·88
Per cent. of tannin by Löwenthal's after removal of pectin,	30·24	26·51	17·83
Per cent. of tannin by Löwenthal's before removal of pectin,	38·48	27·14	18·96
Excess by Löwenthal's after removal of pectin,	3·98	1·87	0·05
Excess by Löwenthal's before removal of pectin,	12·12	2·44	1·08

This table plainly shows: (1) That a like result is obtained by the two methods in the case of the extract that has been refined during the manufacture. (2) That a partially refined extract (one containing more pectin) gives a certain discrepancy between the methods. (3) That when the pectinous matter is still larger, the discrepancy is greater still. This, it is to be noted, is after the pectin has been removed. If the Löwenthal method is applied before the removal of the pectin, the results are still more discordant. It is, therefore, evident: (1) That the gelatin, salt, and acid of Löwenthal's method precipitate out of this extract other matter besides tannin, giving

thus too high a result. (2) If this other matter, which is evidently the "pectin" of the extract, is removed by alcohol precipitation, the results are still high, except when the percentage of the pectin was at first very small, showing the presence of some body, doubtless derived from the pectin, which has escaped separation because soluble in alcohol, and which is, like pectin, counted as tannin by Löwenthal's method, but which hide powder refuses to take up. It is exceedingly probable that this substance is the so-called *metapectic acid*, formed from the pectin after the manufacture of the extract. If a way can be found for its removal, one of the difficulties of tannin estimation in sumac extracts will be overcome; that is, if it is desirable, as Proctor thinks, to retain Löwenthal's method for sumac. It seems to the writer that the hide powder method, when properly used, is preferable, since, as shown above, one of the errors of Löwenthal's method is that which does not seem to affect the hide powder method. H. T.

SILICON MON-OXIDE. Charles F. Mabery (*Am. Chem. Jour.*, **9**, 14).—When silica is reduced in the absence of metals in the Cowles' electric furnace, the product contains a varying quantity of an amorphous, greenish-yellow, or sometimes deep-green substance, having a vitreous lustre. It is always found between the unreduced oxide and the silicon, which seems to show that it is the result of a partial reduction. Analysis of this substance indicates that it is silicon mon-oxide. It is attacked by hydrofluoric acid, but not as readily as the di-oxide, and is slowly changed to the latter by fusion with a mixture of alkaline carbonate and potassium nitrate. A determination of its specific gravity gave 2,893, a figure somewhat higher than the density of silica.

W. H. G.

ON A PARTIAL SEPARATION OF THE CONSTITUENTS OF A SOLUTION DURING EXPANSION BY RISE OF TEMPERATURE. J. W. Mallet (*Chemical News*, **56**, 146).—In a thermometer containing colored alcohol, on several occasions when rise of temperature occurred somewhat gradually after rather severely cold weather, the upper part of the column of liquid was colorless or nearly so, while no deposition of any solid coloring matter could be seen in the bulb or the lower part of the tube. Colorless alcohol had apparently separated by expansion from still perfect solution left behind.

This led to making some experiments with solutions, partly aqueous, partly alcoholic, of several colloid substances, such as starch, tannin, caramel, albumen and gelatin. Each solution was placed in a flask of about half a litre capacity, which was brought to near 0° C. by being surrounded with ice, filled to the mouth with the solution, and closed by a cork traversed by a glass tube, about 4 mm. interior diameter, 15 or 20 cm. long, and having a glass stop-cock in the middle of its length. The ice having been removed, the temperature of the flask and its contents was allowed to rise gradually until the column of liquid in the tube, originally one or two centimetres below the stop-cock, had reached to about as far above it. The stop-cock was then closed, and the small portion of liquid above it was submitted to appropriate tests for the substance in solution in the contents of the body of the flask. In contrast with a sample of equal volume taken from the flask itself, the por-

tion which had been slowly driven up by expansion was found to contain a diminished amount of material in solution, often a very notably diminished amount, and in two or three instances practically none.

The author proposes the term apantlesis to signify this draining away of some of the molecules of the solvent undergoing expansion from those of the colloid solid in solution. W. H. G.

ACTION OF CARBON TETRA-CHLORIDE ON OXIDES. E. Demarçay (*Comp. Rendus*, **104,** 111), and Lothar Meyer (*Berl. Ber.*, **20,** 681), independently. —The preparation of metallic chlorides by the action of chlorine on a heated mixture of the oxide and charcoal, leaves nothing to be desired, if the chloride is readily volatilized, but if it is not, there is often difficulty in separating it from the mixture of charcoal or oxide if an excess of either has been employed. The reaction of the oxides with carbon tetra-chloride would avoid this inconvenience. The authors' results agree in the main; when the reaction occurs, the gaseous products are carbon di-oxide, carbonyl chloride, chlorine, hexachlorethane, and according to Meyer, carbon mon-oxide. Both agree that aluminium oxide is readily reduced and that silica is not. Meyer states that the oxides of beryllium, magnesium and cerium are reduced, while titanium, boron and zirconium oxides are not. Demarçay reduced, in addition, chromium, tantalium and niobium oxides, and states that zirconium oxide is reduced slowly and titanium oxide rapidly at 440°. Meyer does not give the temperature. W. H. G.

VOLATILIZATION OF DISSOLVED SOLIDS DURING EVAPORATION OF THE SOLVENT. By P. M. Delacharlonny (*Comptes Rendus*, **103,** 1,128).—When strong solutions of sodium hydroxide, sodium carbonate and ferric sulphate are heated to 65–70° in vessels covered with inverted funnels, some of the dissolved substance is carried off with the vapor, as may be proved by appropriate test papers placed in the apices of the funnels. The test papers are colored after four or five days, even at ordinary temperatures, and that the solid is not carried off as such in particles is proved by the fact that the test papers become uniformly colored and not in streaks or patches. Acid solutions of alum and of ferric sulphate give similar results at ordinary temperatures. W. H. G.

TOXIC PROPERTIES OF METALS.—These properties are in proportion to the atomic weight and the specific heat of the metal. The theory may be expressed thus: The higher the atomic weight and the lower the specific heat, the more intense is the metallic poison. Lithium furnishes an exception to this law of toxicity of metals; but metallic lithium kills by its convulsing action on the nervous system, and not by the ordinary toxic effect of metals, which is that of destruction of the functional activity of the nervous system. R. L. B.

PHYSIOLOGICAL ACTION OF INSOLUBLE REAGENTS.—In a report of experiments given in *The Journal of Physiology*, **6,** No. 3, by Dr. James Blake, of San Francisco, it is stated that recently precipitated ferric oxide Fe_2O_3, injected into the veins of an animal in small quantities proved instantly fatal; precipitated alumina, Al_2O_3 caused death after a second injection. Barium

sulphate furnished a negative result, the insoluble sulphate producing no effect.

A microscopical examination of the precipitates explained the difference in their physiological action; the aluminium and the ferric oxides were in flakes; the particles of the barium sulphate were thirty times less in size. The Al_2O_3 and Fe_2O_3 would thus prove fatal by causing embolism in the pulmonary capillaries. R. L. B.

THE MAGNESIUM FLASH-LIGHT FOR PHOTOGRAPHIC PURPOSES, as might have been anticipated, has rapidly acquired popularity, but despite words of caution, and in open disregard or ignorance of well-established chemical facts, mixtures of a highly dangerous character have been proposed, and some have been brought into the market; and an explosion in the preparation of such a mixture, of which chlorate of potash and picric acid were ingredients, resulted fatally to the workman. Whilst ignition by means of gun-cotton, previously given, is without danger, a method proposed by Mr. Bishop, before the North London Photographic Society, may be more convenient or comfortable in some cases, whilst it is said to be equally effective. In it the magnesium powder is simply blown into the flame of a spirit lamp supplied with two wicks, one about three inches in front of the other, so that the powder that escapes combustion in the first may be ignited by the other. The magnesium powder is contained in a small wide-mouthed bottle, with two tubes passing through the cork; through one, which dips beneath the powder, the magnesium is suddenly projected into the flame by pressure upon a pneumatic ball attached to the other, which only extends below the cork. The amount of powder delivered to the lamp is easily regulated, and the operation can be repeated until the bottle is emptied. C. F. H.

PHYSICS.

A NOVEL ELECTRO-MAGNET.—Maj. Wm. R. King, of the U. S. Corps of Engineers, has frequently had occasion to exercise his ingenuity in inventing new devices in connection with his military and civil operations.

Since his late transfer to the command of the Engineer School of Application at Willits Point, N. Y., he has been engaged in making some interesting experiments in electro-magnetism on a large scale and with unusual materials.

Two fifteen-inch "columbiads," weighing 50,000 pounds each, were mounted side by side with their axes parallel. Their muzzles were then wound with about eight miles of insulated wire extending over a length of six feet, and the breeches were connected by lashing ordinary railroad rails across them. The net section of this part of the magnet being only about sixty square inches was much too small for the best results; the armature used was also too light, having a section of but eighty-two square inches.

The current was generated by a thirty horse-power dynamo, and the following results were obtained. A pull on the dynamometer chain attached to one end of the armature, detached it, with an indicated tension equivalent to 20,600 pounds if applied at the centre.

It sustained four fifteen-inch shells weighing 320 pounds each, or 1,280 pounds in all, suspended from the muzzle of one of the guns.

The magnetic field was so large that by holding a spike or piece of iron in the hand it was possible to perceive the lines of force even at a distance of from five to six feet and to indicate the curves of their relative directions on paper. By this means a neutral point was found in the axis of the bore of each gun seven and one-half inches in front of the muzzle. Between this point and the gun there was a strong repulsion, while beyond it the attractive forces preponderated.

By placing small pieces of soft iron wire in the axis of the gun they would be shot out about two feet, when the opposite current would draw them suddenly back to the rim of the bore where they would remain fast until the current was broken.

These experiments are of interest as illustrating how even very crude apparatus may be made to contribute to the general fund of scientific knowledge when assembled and directed by a skilful operator. The full strength of the magnet was not developed, in consequence of lack of sufficient materials to properly proportion the several parts. It revives the active interest which was created by the powerful magnets constructed by the illustrious Dr. Joseph Henry, who, when Professor of Physics, at Princeton, about 1831, made a magnet which supported 3,600 pounds by a current from a small electrical battery, "not more than a foot square." This machine is believed to be still a part of the apparatus of Princeton College. It was through these discoveries of Prof. Henry that the electric telegraph became an accomplished fact in 1844. L. M. H.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, February 15, 1888.*]

Hall of the Institute, Philadelphia, February 15, 1888.

Joseph M. Wilson, President, in the Chair.

Present, 101 members and eleven visitors.

Accessions to membership since last meeting, twelve.

Prof. Sam'l P. Sadtler was elected to the Board of Managers, in place of Mr. W. P. Tatham, whose election to the position of Vice-President at the last annual election caused a vacancy.

Prof. Lewis M. Haupt, of the University of Pennsylvania, by invitation, made an address in which he dwelt upon the important and intimate relations existing between the growth of a great city and the development of its means for promoting external and interior traffic, drawing his illustrations from the experiences of London and New York. He explained, in conclusion, the plan of an underground railway proposed for the City of Philadelphia.

Mr. FRED. E. IVES made some further remarks upon the "Japanese Magic Mirror," in the course of which he stated that he had learned from Prof. WM. A. ANTHONY, since the publication of his remarks at a previous meeting, that he had been anticipated in the explanation he had offered to account for the production of the magic image, by M. DUBOSQ, the well-known maker of philosophical apparatus, in Paris.

The Secretary exhibited, in the course of his report, a suite of interesting specimens of electric-welding, presented to the INSTITUTE by the Thomson Electric-Welding Company, of Lynn, Mass.

The Secretary exhibited also a series of fine and elaborately-decorated articles of solid silver, made by electro-deposition. The makers were Messrs. Thomas G. Brown & Sons, of Newark, N. J.

The President announced the appointment of the following, to constitute the Standing Committees of the INSTITUTE for the current year, viz.:

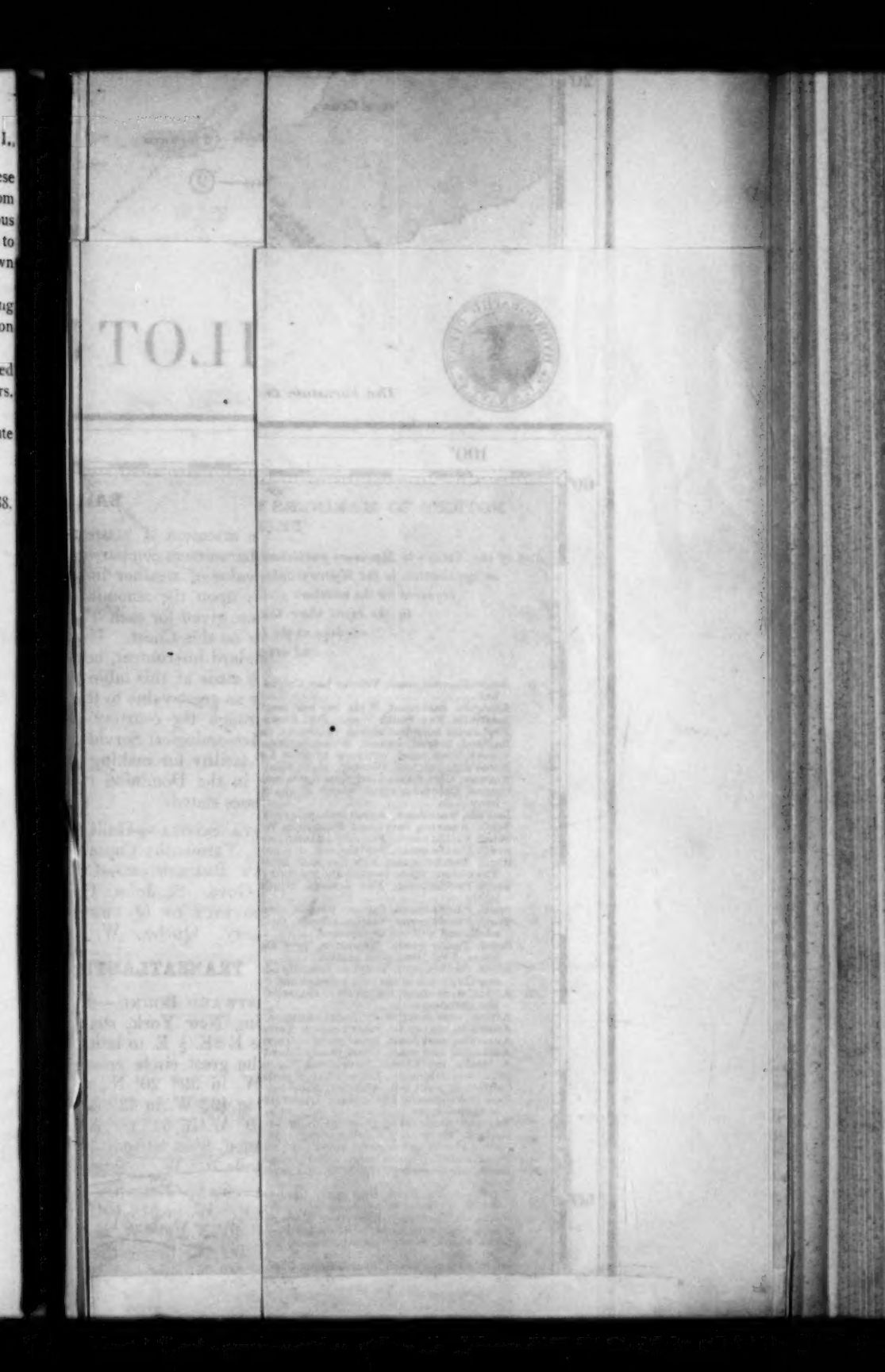
STANDING COMMITTEES OF THE FRANKLIN INSTITUTE FOR THE YEAR 1888.

Library.	*Minerals.*	*Models.*
Charles Bullock,	Clarence S. Bement,	Edward Brown,
J. Howard Gibson,	Persifor Frazer,	John H. Cooper,
Frederick Graff,	F. A. Genth,	C. Chabot,
Geo. A. Koenig,	Edwin J. Houston,	L. L. Cheney,
S. H. Needles,	George A. Koenig,	N. H. Edgerton,
Isaac Norris, Jr.,	Otto Lüthy,	John Goehring,
John C. Trautwine, Jr.,	E. F. Moody,	Morris L. Orum,
Chas. E. Ronaldson,	H. Pemberton, Jr.,	Chas. Richardson,
Wm. P. Tatham,	Theo. D. Rand,	John J. Weaver,
Lewis S. Ware.	Wm. H. Wahl.	S. Lloyd Wiegand.

Arts and Manufactures.	*Meteorology.*	*Meetings.*
J. Sellers Bancroft,	Lorin Blodget,	Hugo Bilgram,
George Burnham,	Charles M. Cresson,	Geo. V. Cresson,
Cyrus Chambers, Jr.,	Edwin J. Houston,	G. M. Eldridge,
Wm. Helme,	Isaac Norris, Jr.,	Fred'k Graff,
Wm. B. Le Van,	Alex. E. Outerbridge, Jr.,	Henry R. Heyl,
Alfred Mellor,	J. S. W. Phillips,	Washington Jones,
C. C. Newton,	M. B. Snyder,	Sam'l R. Marshall,
Henry Pemberton,	Wm. P. Tatham,	G. H. Perkins,
E. Alex. Scott,	N. Wiley Thomas,	Chas. E. Ronaldson,
Wm. Vollmer.	Wm. H. Wahl.	Wm. H. Thorne.

Adjourned.

WM. H. WAHL, *Secretary.*



HYDROGRAPHIC OFFICE U.S.NAVY

The Variation is for 1885

PI

100° 90° 80° 70°

60° 50° 40° 30°

NOTICES TO MARINERS ISSUED DURING THE MONTH OF FEBRUARY, 1888.

Any of the Notices to Mariners published by the Hydrographic Office will be sent, free of charge, on application to the Hydrographer. In making applications, designate the notices required by the numbers given in the left margin. The smaller figures in the right show the number of the paragraph. Files are kept at the Branch Hydrographic Offices and are open to examination.

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Dangerous Obstructions to Navigation along the Coast.

NOTE.—This list is compiled from all available data, and is corrected up to the hour of going to press. Reports as to the continued existence or the removal of any of these obstructions are specially requested from masters of vessels passing in their vicinity.

Latitude 44° 40' N., longitude 60° 22' W.: Vessel's mast 8 feet out of water. Reported November 10.

Cape Elizabeth west, 8 miles: Sunken schooner; masts out of water. Reported January 2.

Sankaty light, North 12 miles: A wreck in 11 fathoms. Last reported August 28.

Monomoy point light NW. by N., ½ mile: Sunken schooner; mast-heads out of water. Reported December 22.

Nantucket New South shoal light-ship N NW., 4 miles: Sunken steamer Newcastle City in 13½ fathoms water; masts from 6 to 8 feet above water; a dangerous obstruction. Reported January 10.

Bishop and Clark's light NW. by W., 5 miles: Sunken schooner Panope, in 6 fathoms; topmasts above water; buoyed. Reported February 15.

Judith point: Schooner Mary A. Drury; hull still holds together; spars standing. Last reported January 10.

Falkner's island, NE. by E.; Branford reef beacon, NW. ½ N.: Sunken schooner Helen Augusta; mast 4 feet above water. Reported January 13.

Gull island light, E SE.; Bartlett's reef light, N.: Sunken schooner Wm. M. McKay. Reported February 6.

Shinnecock light W NW. ½ W., 4 miles: Sunken schooner. Reported December 21.

Off Barnegat: Schooner "Lizzie Wilson." Sunk August 18.

Barnegat N. ½ W., 3 miles: A sunken wreck in 9 fathoms of water. Reported December 22.

Barnegat light-house SW. by S., 12½ miles: Pilot-boat Francis Perkins in 11 fathoms of water; masts broken off 3 fathoms under water. Last reported September 16.

Barnegat NW. by W. ½ W., 9 miles: Sunken wreck; one mast out of water. Last reported October 3.

Tucker's beach light-house W. ½ N., 11 miles: Sunken schooner Nellie S. Jarrell. Located December 13.

Tucker's beach light-house W. by N., 8½ miles: Schooner Mariotta Steelman. Reported to be breaking up October 11. Also, about 1,000 feet N. by W. from this wreck, steamer E. C. Knight. Last reported October 17.

Absecum NW., 20 miles: Sunken schooner Katie Ranger. Foundered December 18; position uncertain.

Absecum light West, 8 miles: Sunken schooner; one mast 10 feet above water. Reported February 1.

[illegible] miles: Sunken schooner; masts 15 feet above water. Reported [illegible]

Cape Henry light South, 4 7/10 miles: Sunken schooner E. B. Everman, in 7½ fathoms; buoyed. Last reported December 28.

Lambert's point light-house ENE. ¼ E.: Coal-barge Marion sunk in mid-channel; a white light at night. Reported December 28.

Currituck NW., 20 miles: Sunken bark Samuel Welsh. Reported February 25.

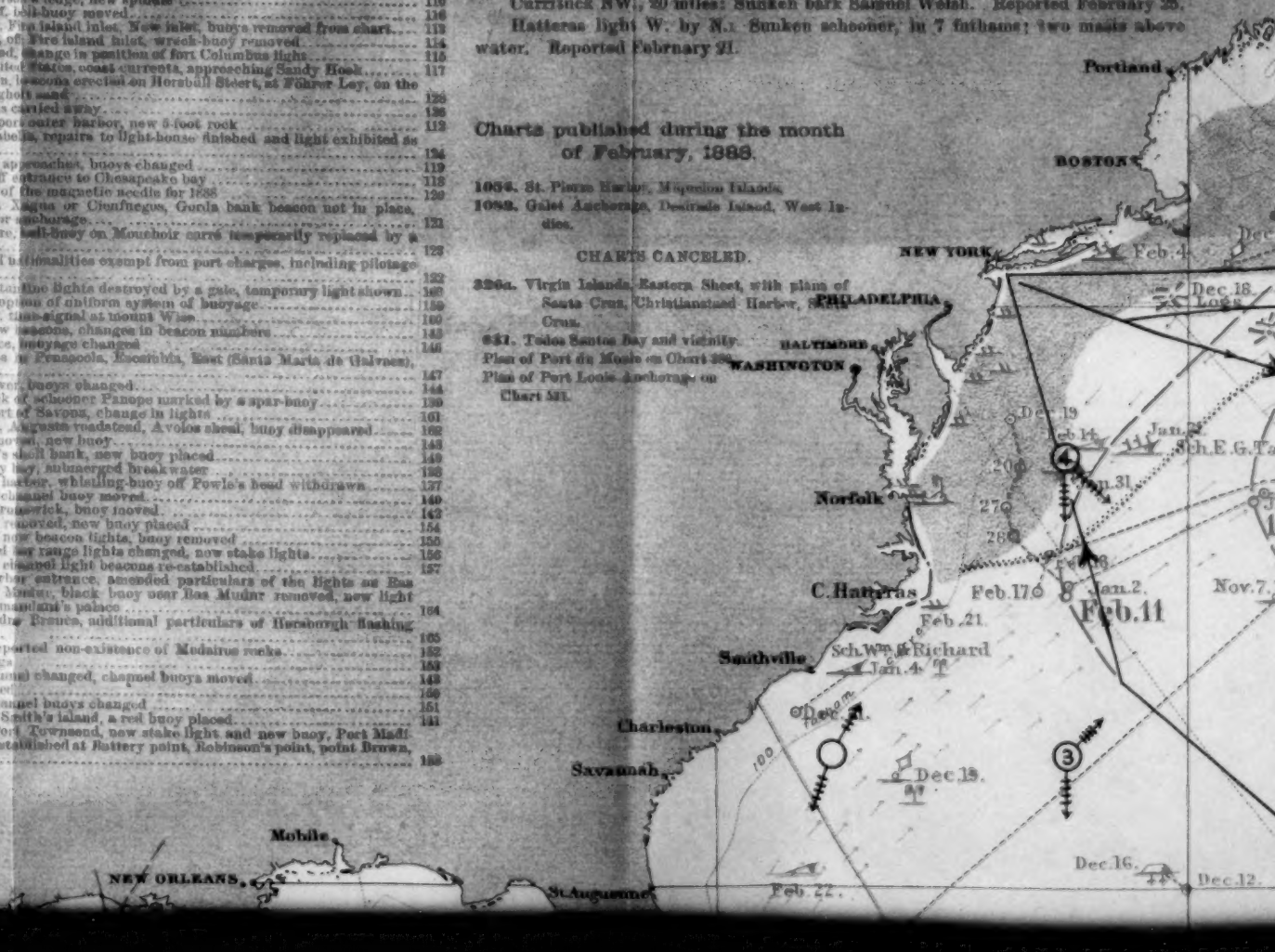
Hatteras light W. by N.: Sunken schooner, in 7 fathoms; two masts above water. Reported February 21.

Charts published during the month of February, 1888.

1036. St. Pierre Harbor, Miquelon Islands.
1092. Galet Anchorage, Desirade Island, West Indies.

CHARTS CANCELED.

320a. Virgin Islands, Eastern Sheet, with plans of Santa Cruz, Christiansted Harbor, and Cruz.
331. Todos Santos Bay and vicinity.
Plan of Port du Moule on Chart 330.
Plan of Port Louis Anchorage on Chart 331.



PILOT CHART OF THE NORTH ATLANTIC OC

70° 60° 50° 40°

BAROMETER COMPARISONS.

The attention of masters of vessels is called to the importance of having their barometers compared with Standards as often as possible, as the practical value of weather indications furnished by the barometer depends very largely upon the amount it reads above or below the normal at the ship's position, given for each 5° ocean square in the table accompanying the weather review on this Chart. Unless the barometer has been recently compared with a Standard instrument, however, and its exact error obtained, no practical use can be made of this table of barometer normals, nor are such observations of nearly as great value to the Hydrographic Office.

Through the courtesy of Professor Charles Carpmael, Superintendent of the Meteorological Service of Canada, arrangements have been made by which every facility for making such comparisons can be obtained at the following ports in the Dominion of Canada, and communications may be sent to the addresses stated:

NOVA SCOTIA.—Halifax: Augustus Allison. Sydney, C. B.: Thomas C. Hill. Yarmouth: Captain J. E. Murphy.

NEW BRUNSWICK.—Chatham: D. T. Johnston, Esq. St. Andrews: S. T. Gove. St. John: George Hutchinson, Observatory.

PROVINCE OF QUEBEC.—Montreal: C. H. McLeod, McGill College Observatory. Quebec: W. A. Ashe, Observatory.

TRANSATLANTIC STEAMSHIP ROUTES FOR MARCH.

EASTWARD BOUND.—Follow this track, or nothing to the northward of it. Leaving New York, steer for latitude 40° 26′ N., longitude 72° 46′ W.; thence E SE. ½ E. to latitude 39° 50′ N., longitude 71° 30′ W.; thence follow the great circle crossing 70° W. in 39° 56′ N., 60° W. in 46° 04′ N., 50° W. in 39° 20′ N., and 47° 20′ W. in 39° N.; thence the great circle crossing 40° W. in 42° 50′ N., 30° W. in 46° 49′ N., 20° W. in 49° 25′ N., and 10° W. in 51° 00′ N. To the English channel follow the great circle, as plotted, from latitude 39° N., longitude 47° 20′ W., to latitude 49° 30′ N., longitude 7° W.

WESTWARD BOUND.—Follow this track, or nothing to the southward of it. Cross 10° W. in 51° 10′ N.; thence follow the great circle crossing 20° W. in 49° 40′ N., 30° W. in 47° 10′ N., 40° W. in 43° 38′ N., and 47° 20′ W. in 40° 00′ N.; thence the great circle crossing 50° W. in 40° 20′ N., 60° W. in 40° 50′ N., and 69° W. in 40° 38′ N.; then keep inside 30 fathoms, steering to cross 74° W. in 40° 30′ N. From the English channel follow the route plotted, steering W. ¼ N. from latitude 49° 30′ N., longitude 7° W., as far

THE LOGS OF THE GREAT RAFT.

Although nearly two and one-half months have passed since the great raft was abandoned south of Nantucket, reports continue to be received from vessels falling in with the logs, which are now widely separated. The general drift has been in an ESE. direction, the logs being found a little to the southward of this line. That they were not carried more to the northward and eastward by the Gulf stream, as would be expected, was probably due to the strong NW. winds which prevailed during the latter part of December and the first part of January. Fortunately no vessel has been [illegible] with them, although the German bark "[illegible]" which was [illegible] with the logs for 5 days, in latitude 40° 00′ N., longitude 62° 00′ W., had her sheathing torn and rudder injured. The latest reports of the logs having been seen are as follows: British steamer "Hampshire," January 24, in latitude 36° 17′ N., longitude 58° 36′ W.; British steamer "Pic[illegible]" January 27, in latitude 36° 40′ N., longitude 56° 25′ W.; German bark "Marie" was amongst the logs for several days, January 9 to 13, about latitude 38° N., longitude 50° to 60° W.; and the British steamer "Empire," February 22 and 23, in latitude 37° N., longitude 59° to [illegible] W.

NOTES

TO THE NORTH SEA [illegible] sailing vessels are often [illegible] accompanying an area of [illegible] ward of this area of high [illegible] erly winds, and it therefo[illegible] sels bound for ports in th[illegible] take a route to the nort[illegible] sea room, and little or no[illegible] ing this route can be rea[illegible] southerly winds are enco[illegible] high and steady barome[illegible] to the north of Scotland, [illegible] of the Channel, where e[illegible]

TO THE MEDITERRA[illegible] and April should not cr[illegible] of cape St. Vincent, as [illegible] creasing frequency, to th[illegible]

NOVA SCOTIA
Halifax
Sable I.
Sable
NEWFOUNDLAND
Farewell
Feb. 1
Feb. 9
Feb. 13
Jan. 1
Jan. 2
Jan. 3
Jan. 4
Jan. 9
Jan. 10
Jan. 14
Jan. 15
Jan. 16
Jan. 18
Jan. 24
Jan. 27
Jan. 31
Dec. 7
Dec. 12
Dec. 18
Dec. 21
Dec. 24
Dec. 25
Dec. 27
Dec. 28
Nov. 7
Nov. 23
Oct. 3
Oct. 13
Oct. 18
Oct. 30
Sept. 18
Feb. 10
Feb. 11
Feb. 15
Sch. Cordelia
Sch. Regardless
Sch. D. & E. Kelley
Sch. L. A. Danenhower
Sch. E. G. Taufline
Sch. M. V. Co[illegible]
Bk. Lalia
Bk. Telemach
Bk. Carribean
Brt. Warren W.
Bermuda
Georges Shoal
SAILING ROUTE TO EQUATOR.
SAILING

HART OF THE NORTH ATLANTIC OCEAN

60° 50° 40° 30°

R COMPARISONS.

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ndards as often as possible, as the prac-
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nd its exact error obtained, no practical use
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graphic Office.
ssor Charles Carpmael, Superintendent of
ada, arrangements have been made by which
upar[illegible]'s can be obtained at the following
s, and communications may be sent to the

ustus Allison, Sydney, C. B.: Thomas C.
Murphy.
D. T. Johnston, [illegible], Esq., St. Andrews;
utchinson, Observatory.
treal: C. H. McLeod, McGill College Ob-
Observatory.

AMSHIP ROUTES FOR MARCH.

his track, or nothing to the northward of it:
titude 40° 26′ N., longitude 73° 46′ W.
50′ N., longitude 71° 30′ W.; thence fol-
W. in 39° 56′ N., 60° W. in 40° 04′ N.,
20′ W. in 39° N.; thence the great circle
0° W. in 46° 49′ N., 20° W. in 49° 25′ N.,
he English channel, follow the great circle,
ongitude 47° 20′ W., to latitude 49° 30′ N.,

this track, or nothing to the southward of it:
ace follow the great circle crossing 20° W.
N., 40° W. in 43° 38′ N., and 47° 20′ W.
rcle crossing 50° W. in 40° 20′ N. 60° W.
° 38′ N.; then keep inside 30 fathoms, steer
From the English channel, [illegible] route
atitude 48° 30′ N., longitude 7° W., as far

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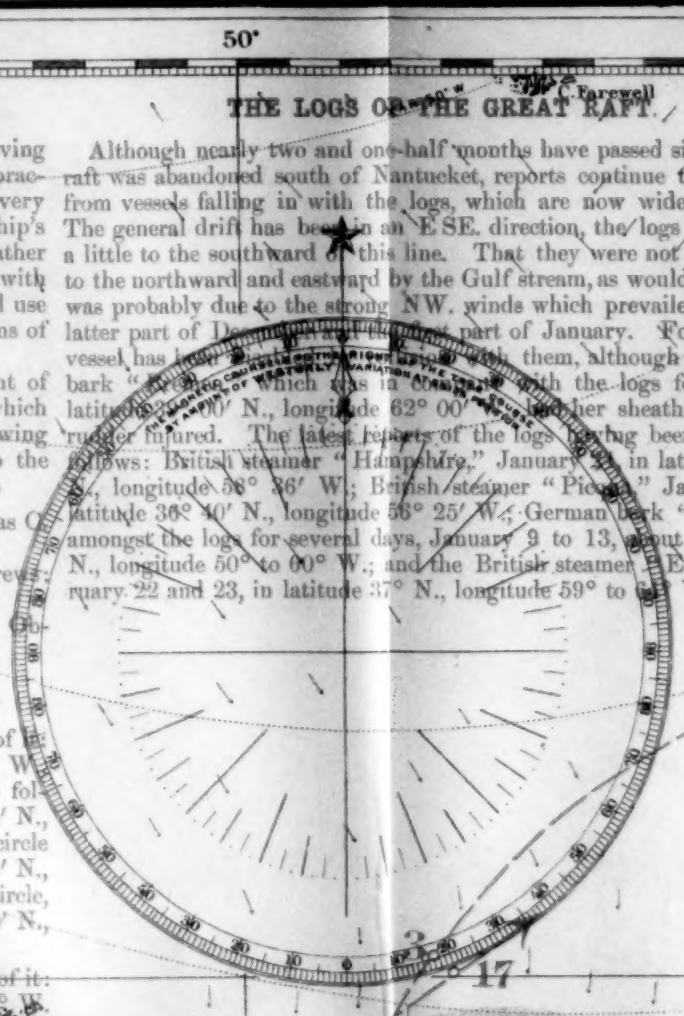
NOTES ON BEST SAILING RO

To the North sea and the Baltic.—During sailing vessels are often delayed in the Channel by accompanying an area of high barometer over the Brit ward of this area of high barometer there are correspo erly winds, and it therefore follows that under such c sels bound for ports in the North sea and the Baltic c take a route to the north of Scotland. On this rout sea room, and little or no danger of collision. Favor ing this route can be readily determined out in mid- southerly winds are encountered to the eastward of th high and steady barometer, there should be no hesita to the north of Scotland, instead of attempting to tak of the Channel, where easterly winds are then likely

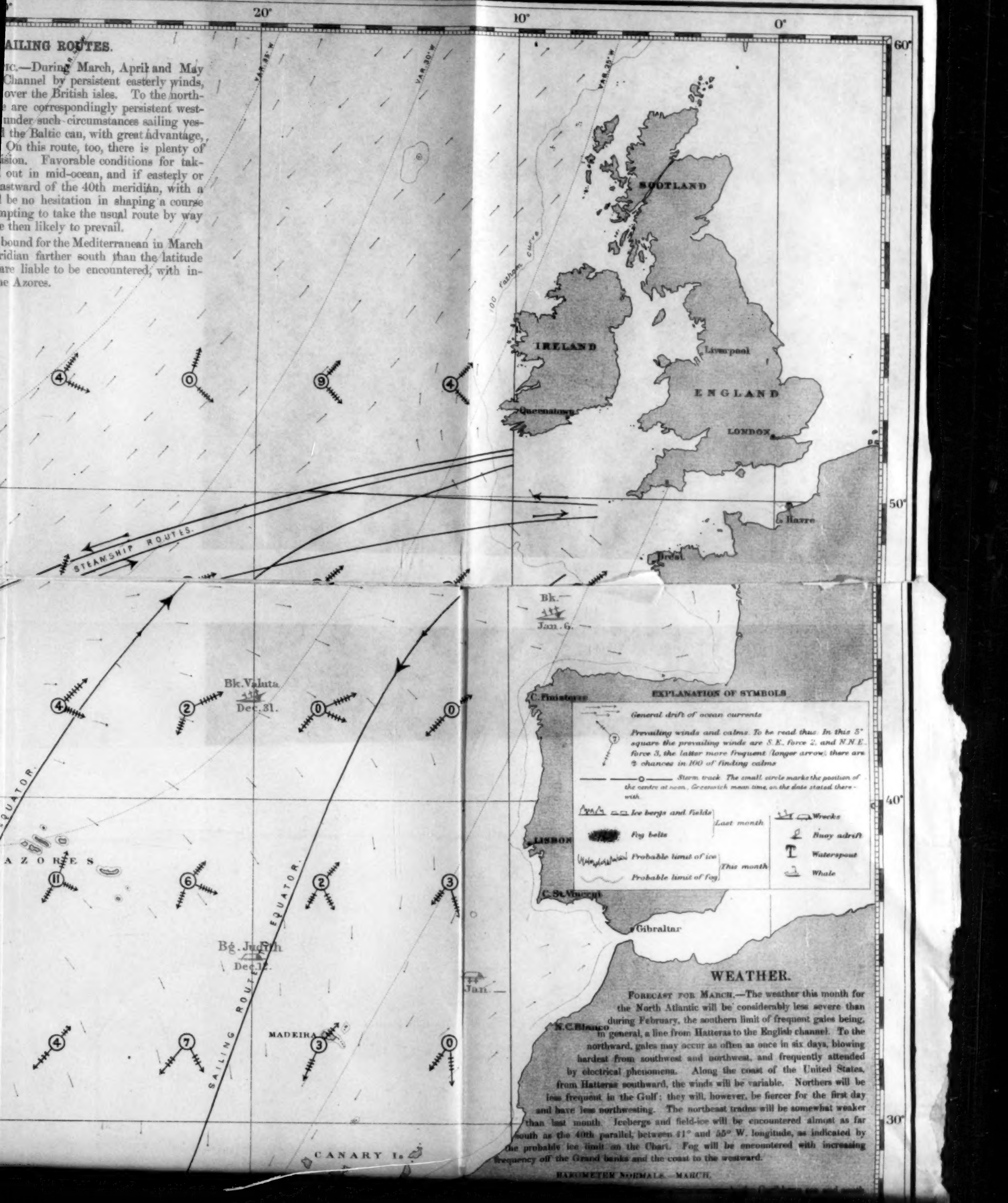
To the Mediterranean.—Vessels bound for the and April should not cross the 20th meridian farther of cape St. Vincent, as northerly winds are liable to creasing frequency, to the eastward of the Azores.



AILING ROUTES.

IC.—During March, April and May Channel by persistent easterly winds, over the British isles. To the north- e are correspondingly persistent west- nder such circumstances sailing ves- l the Baltic can, with great advantage, On this route, too, there is plenty of ision. Favorable conditions for tak- out in mid-ocean, and if easterly or astward of the 40th meridian, with a l be no hesitation in shaping a course mpting to take the usual route by way e then likely to prevail.

bound for the Mediterranean in March ridian farther south than the latitude are liable to be encountered, with in- ne Azores.



WEATHER.

FORECAST FOR MARCH.—The weather this month for the North Atlantic will be considerably less severe than during February, the southern limit of frequent gales being, in general, a line from Hatteras to the English channel. To the northward, gales may occur as often as once in six days, blowing hardest from southwest and northwest, and frequently attended by electrical phenomena. Along the coast of the United States, from Hatteras southward, the winds will be variable. Northers will be less frequent in the Gulf; they will, however, be fiercer for the first day and have less northwesting. The northeast trades will be somewhat weaker than last month. Icebergs and field-ice will be encountered almost as far south as the 40th parallel, between 41° and 55° W. longitude, as indicated by the probable ice limit on the Chart. Fog will be encountered with increasing frequency off the Grand banks and the coast to the westward.

BAROMETER NORMALS.—MARCH.

Feb. 1

Jan. 22.

Jan. 24. Logs

Jan. 27. Logs

Bk. Lalia.

Sept. 18.

Oct. 13.

Oct. 3.

SAILING ROUTE TO EQUATOR.

Jan. 9.

Bgt. Warren W.

Oct. 18.

Dec. 3.

Oct. 13.

Dec. 31.

Bg. Jura.

Jan. 6.

SAILING ROUTE FROM EQUATOR.

Bk. Telemach.

Jan. 27.

Dec. 25.d

Jan. 18.

Jan. 19.

Jan. 9.

Oct. 30.

Sp. Alfred Watts

Nov. 20.

Nov. 26.

Bk. Vincenzo Perrotta.

Feb. 11.

FROM EQUATOR.

NORTHERN LIMIT OF THE N.E. TRADES.

SAILING ROUTE BY WAY OF THE TRADES.

Barbados

NO VARIATION

Demerara R.

Cayenne

REGION OF EQUATORIAL RAINS.

SOUTHERN LIMIT OF THE N.E.

NORTHERN LIMIT OF THE S.E.

St. Paul Rocks

Amazon R.

60° 50° 40° 30°

the frequency of the
Beaufort's scale.
g in prompt and complete reports of
ications may be handed to the U. S.
lices are established in the United States as follows:

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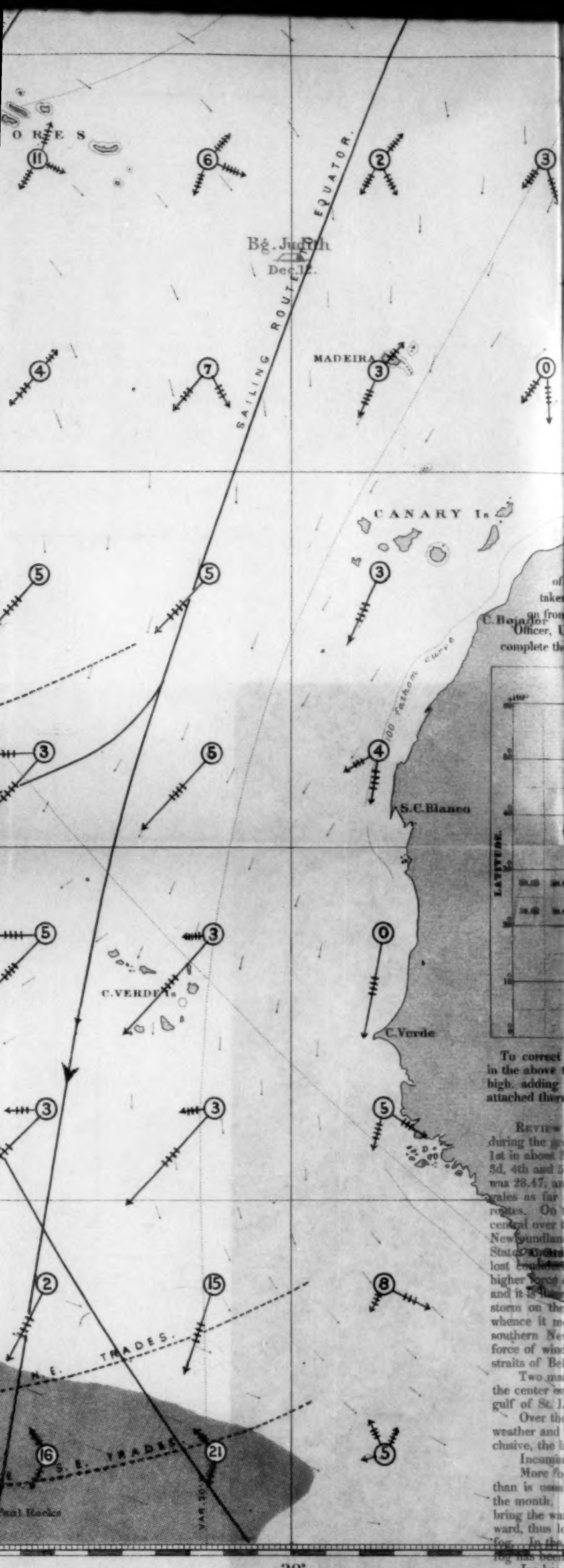
s: Maritime Association, No. 7 Varieties Alley.
sco: Merchants' Exchange.

ed free of expense, and the latest information can
atters of interest to commerce.

Published Monthly at the Hydrographic Office, Navy Department, Washington, D. C.
J. R. Bartlett, Commander, U. S. N., Hydrographer to the Bureau of Navigation.



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BAROMETER NORMALS.—MARCH.

These normals, with the exception of those for ocean squares in the Caribbean sea and south of the 10th parallel have been computed from the simultaneous meteorological observations taken by international co-operation and published by the U. S. Signal Service. They are based on from seven to nine years' observations, and have been specially prepared by the Chief Signal Officer, U. S. Army, for the use of the Pilot Chart, in advance of their regular publication. To complete the table, figures have been added from other reliable data.

LATITUDE.	LONGITUDE.														
	100°	90°	80°	70°	60°	50°	40°	30°	20°	10°					
60°							29.66	29.67	29.65	29.69	29.74	29.77	29.80	29.81	
50°							29.77	29.78	29.76	29.81	29.85	29.86	29.84	29.84	
40°							29.89	29.89	29.85	29.89	29.91	29.90	29.87	29.89	
30°					29.94	29.90	29.86	29.82	29.81	29.85	29.81	29.85	29.82	29.81	
20°				29.91	29.89	29.94	29.94	29.97	29.90	29.93	29.93	30.05	30.14	30.19	30.09
10°			30.05	30.05	30.04	30.05	30.03	30.07	30.11	30.14	30.17	30.17	30.16	30.13	30.10
0°		29.98	29.95	29.99	30.01	30.11	30.11	30.10	30.09	30.11	30.13	30.17	30.17	30.15	
10° S.		29.98	29.94	29.97	29.99	29.98	30.01	30.13	30.11	30.11	30.12	30.14	30.13	30.12	30.10
20° S.				29.92	29.96	30.04	30.02	30.03	30.07	30.07	30.10	30.09	30.08	30.08	
30° S.					29.96	29.99	29.99	30.00	30.00	29.99	30.04	30.06	30.05	30.04	30.01
40° S.										29.97	29.97	29.97	29.97	29.97	29.97
50° S.												29.90	29.93	29.90	29.92

To correct the observed reading of a vessel's barometer, in order to compare it with the normal given in the above table, apply first the error shown by last comparison with standard, subtracting this error if high, adding if low. Then, if mercurial, subtract a small correction depending on the reading of the attached thermometer, as follows: Attached thermometer, 40°, correction, .08; 50°, .06; 60°, .08; 70°, .11.

REVIEW OF FEBRUARY.—Fresh westerly winds have prevailed over the transatlantic steamship routes during the greater part of the month, and a cyclonic disturbance of considerable severity was central on the 1st in about 39° N. and 57° W., moving northeasterly. It crossed the Grand banks on the 2d, and on the 3d, 4th and 5th moved eastward about the 54th parallel; the lowest corrected barometer reading reported was 28.47, and the highest force of wind 11, of Beaufort's scale. This storm was accompanied by strong gales as far south as the 30th parallel, with heavy snow, hail, and sleet along the transatlantic steamship routes. On the morning of the 9th an area of low pressure, which had advanced from the continent, was central over the eastern portion of the gulf of St. Lawrence, and by the 10th it had passed eastward over Newfoundland. Two cyclonic storms passed in close succession along the Atlantic coast of the United States to the Grand Newfoundland. Both seem to have originated in the vicinity of the Bermudas, and to have lost considerable energy after passing the 40th parallel, north of which no report has been received of a higher force of wind than 9. The first of these was central about 120 miles east from Hatteras on the 11th, and it is interesting to note that large waterspouts were reported by vessels in the southwest quadrant of this storm on the 10th and 11th. The second was central about 500 miles east from Hatteras on the 13th, whence it moved on the usual parabolic track to the northward and then to the northeastward, crossing southern Newfoundland on the 16th, and disappearing north of the 50th parallel. A storm of highest force of wind 10 was central at the mouth of the St. Lawrence river on the 21st, moving thence over the straits of Belle Isle.

Two marked depressions crossed the gulf of Mexico, one in the eastern part on the 2d, the other in the center on the 23d. The latter traversed the United States to the Great Lakes and was central in the gulf of St. Lawrence on the 25th. But one norther was felt in the gulf.

Over the British isles barometric pressure was generally high until the 10th, from which date unsettled weather and low and fluctuating barometer continued until after the 13th. From the 14th to the 18th, inclusive, the barometer was high east of the 30th meridian.

Incoming steamers report very mild weather during the latter part of the month.

More fog has been experienced off the Grand banks and along the Atlantic coast of the United States than is usual during February, owing to the frequent depressions that moved through those regions during the month. These depressions, in the eastern quadrants of their areas, cause strong southerly winds, which bring the warm, moist air from over the Gulf stream into contact with the colder atmosphere to the northward, thus lowering the temperature of the former below the dew-point and precipitating its moisture as fog. In the vicinity of the British isles, however, where high barometric pressure has prevailed, but little fog has been noticed.

Ice has begun to descend, reports having been received of large fields between 50° W. and 63° W., and as far south as 44° N.

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Santa Cruz, Christiansted H... Cruz.

841. Tobio Santos Bay and vicinity.

Plan of Port du Moule on Chart 38...

Plan of Port Louis Anchorage on Chart 161.

40°
30°
20°
10°
0°
100°
90°
80°

Charleston
Savannah
Mobile
NEW ORLEANS
St. Augustine
Galveston
Lizzie Ella
Dec. 27
100 fathom curve
Dec. 29.
Feb. 23
Feb. 2
Nov. 3.
Jan. 5
Key West
Dec. 18.
Campeche
Vera Cruz
Belize
CUBA

STORM CARD.

NORTHERN HEMISPHERE.

REMARKS.

The courses here given are for the wind 2 points on the starboard quarter, but if sea and wind permit, bring the wind broad on the quarter. If in either of these positions there be danger of broaching-to, run before the wind until more moderate and then bring wind on starboard quarter.

A ship having the wind steady is on the storm-track and should run before the wind, note the course and keep it.

ABBREVIATIONS.

Nd = northward	ch = change
Ed = eastward	h = heave-to
Sd = southward	Std = starboard
Wd = westward	P = Port

N
E
S
W

NE wind ch to Ed. h. Std tack ch to Sd. run SE or h. P tack
ENE wind ch to Ed. h. Std tack ch to Sd. run SE or h. P tack
East wind ch to Sd. h. Std tack ch to Nd. run NNE or h. P tack
ESE wind ch to Sd. h. Std tack ch to Ed. run NE or h. P tack
SE wind ch to Sd. h. Std tack ch to Ed. run NNE or h. P tack
SSE wind ch to Wd. h. Std tack ch to Ed. run North or h. P tack
South wind ch to Wd. h. Std tack ch to Ed. run NNE. or h. P tack
SSW wind ch to Wd. h. Std tack ch to Sd. run NE or h. P tack
SW wind ch to Wd. h. Std tack ch to Sd. run ENE or h. P tack
WSW wind ch to Wd. h. Std tack ch to Sd. run East or h. P tack
West wind ch to Nd. h. Std tack ch to Sd. run ESE or h. P tack
WNW wind ch to Nd. h. Std tack ch to Wd. run SE or h. P tack
NW wind ch to Nd. h. Std tack ch to Wd. run SSE or h. P tack
NNW wind ch to Wd. h. Std tack ch to Wd. run South or h. P tack
North wind ch to Ed. h. Std tack ch to Wd. run SSW or h. P tack
NNE wind ch to Ed. h. Std tack ch to Nd. run SW or h. P tack
NE wind ch to Ed. h. Std tack ch to Nd. run WSW or h. P tack
ENE wind ch to Ed. h. Std tack ch to Nd. run West or h. P tack
East wind ch to Sd. h. Std tack ch to Nd. run NNW or h. P tack
ESE wind ch to Sd. h. Std tack ch to Nd. run NW or h. P tack
SE wind ch to Sd. h. Std tack ch to Ed. run NNW or h. P tack
SSE wind ch to Sd. h. Std tack ch to Ed. run North or h. P tack

Division of Marine Meteorology, Everett Hayden.

Christiansted Harbor, ST. CROIX

PHILADELPHIA

BALTIMORE

WASHINGTON

Norfolk

C. Hatteras

Smithville

Sch. Wm. & Richard Jan. 4

Dec. 18 Logs

Dec. 24. Logs

Jan. 22.

Feb. 1

Jan. 4. Logs

Sch. E. G. Tarbone Jan. 31

Sch. D. & E. Kelley Jan. 10

Jan. 3. Logs

Jan. 27. Logs

Bk. Lalia

Jan. 24. Logs

Sept. 18.

Oct. 13.

Oct. 3.

SAILING ROUTE TO EQUATOR.

Dec. 27.

Feb. 17

Jan. 2.

Feb. 11

Nov. 7.

Dec. 27.

Feb. 13

Feb. 21.

Jan. 9.

Dec. 28.

Sch. L. A. Dane Jan. 16

Bermuda

Bgt. Warren W. Jan. 2

Dec. 18.

Dec. 12.

Jan. 3.

Dec. 19.

Dec. 16.

Dec. 12.

Jan. 11.

Feb. 22.

Sch. M. V. Cook Jan. 15.

Bk. Carribean Dec. 6.

Oct. 30.

SAILING ROUTE FROM EQUATOR.

Dec. 16.

Dec. 21.

Jan.

Dec. 3

Dec. 15.

Sp. Alfred Watts Nov. 26.

Nov. 20

Bk. Vincenzo Perrotta Feb. 11.

July 23.

Jan. 29.

BAHAMA I.

Sch. Henrietta Dec. 10.

CUBA

NORTHERN

SANTO DOMINGO

JAMAICA

PUERTO RICO

St. Thomas

WARD I.

Barbados

Maracaybo

Aspinwall

VAR. 5° E.

NO VARIATION

Demerara R.

Cayenne

Amazon R.

EXPLANATION.

This chart is issued the 1st day of each month, the object being to supply an accurate track chart, and at the same time present graphically as much information as possible of timely interest and value to mariners.

The statement of information collected during the month preceding the date of issue appears on the chart in RED, while the matter in BLUE gives a general meteorological forecast, with deductions therefrom, for the current month.

The drift of a derelict is indicated by the line of dashes connecting the positions where it has been reported, the date of each report being stated at the corresponding position. In reporting a derelict vessel or drifting buoy, special care should be taken to give as exact a description as possible, in order that it may be identified.

The arrows fly with the wind; their lengths are directly proportional to the frequency of the prevailing winds, the number of cross-bars denoting the force, according to Beaufort's scale.

Masters of vessels are requested to co-operate with this Office by sending in prompt and complete reports of marine data immediately upon arrival in port. In foreign ports such communications may be handed to the U. S. Consul, who will forward them free of all expense. Branch Hydrographic Offices are established in the United States as follows:

BOSTON: Custom House.
NEW YORK: Maritime Exchange, Produce Exchange Building.
PHILADELPHIA: Maritime Exchange, 131 South Second Street.
BALTIMORE: Board of Trade, 54 Exchange Place.
NEW ORLEANS: Maritime Association, No. 7 Varieties Alley.
SAN FRANCISCO: Merchants' Exchange.

At these offices barometers and thermometers are compared and adjusted free of expense, and the latest information can always be obtained regarding charts, lights, dangers to navigation, and all matters of interest to commerce.

80° 70° 60° 50°

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J.R. Bartlett, Commander, U.S.N., Hydrographer